THE FOOD LEGUMES

Recommendations for Expansion and Acceleration of Research to Increase Production of Certain of These High-Protein Crops

by Lewis M. Roberts

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CONTENTS

Introduction . . . .

Diversity of the Food Legume Crops . . . .

Recommendation as to the Priority of Food Legume Crops on which Initial Increased Effort Should Be Focused. . . . .

Recommended Approach to Expanding and Accelerating Research on the Six Selected Food Legume Crops . . . .

Rationale for the Assignment of the Crops to the Specific International Institutes as Recommended. . . . .

Role of a Center in Worldwide Networks of Institutions Concerned with Improving the Different Major Food Legume Crops . . . .

International Center Responsibilities and Functions. . . . .

Projects of Common Interest that Should Be Jointly Undertaken by the International Centers Involved . . . .

Staffing Requirements of an International Center . . . .

Needs for Additional Capital Development Funds . . . .

Continuity of Effort, a Prime Requisite for Success. . . . .

THE FOOD LEGUMES[1]

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by Lewis M. Roberts

The food needs of the world's rapidly growing population are not being adequately met. Mankind faces no more complex or urgent task than that of bringing the population-food supply equation into more rational balance. The possibility that this can be done undoubtedly exists, but whether man will take advantage of the means available to him to accomplish it is still an unanswered question. Success will depend on much greater and more concerted efforts on the part of governments, multinational institutions, and private organizations and individuals to bring about advances on both sides of the equation.

The recent dramatic achievements in increased production of rice, wheat, and maize in several countries around the world, especially in Southeast Asia, give us hope that the world's food supply can be increased to adequately feed growing populations for the next decade or so, while measures are taken to reduce the present rate of population expansion.

Despite the "green revolution," as these achievements are popularly labeled, the fact remains that many more people in the world today are suffering from malnutrition than are well fed. This can mean that they are not getting enough to eat (shortage of calories to produce energy) or that their diet lacks the proper balance of the vital nutritive elements, particularly protein, to produce sound growth and reasonable good health. Most of the hungry people in the world suffer from both these deficiencies.

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[1] Food legumes as here defined include those species of the plant family Leguminosae (pea or bean family) that are consumed directly by human beings, most commonly as mature, dry seeds, but occasionally as immature, green seeds or as green pods with the immature seeds enclosed. It does not include species that provide leaf or stem tissue that is used as cooked or uncooked greens. Food legumes utilized as dry seed are often referred to as pulses or grain legumes.

There is a growing awareness that the protein deficit problem is one of the most critical, complex aspects of the total food problem. Vast numbers of people around the world die each year either directly or indirectly from protein starvation, even though many of them may eat reasonable amounts of starchy or high-carbohydrate foods, such as cassava, bananas, yams, sweet potatoes, and rice. We now know that it is not enough to have simply a satisfactory level of total protein intake, but that the diet must contain a reasonably acceptable balance of the protein building blocks, the essential amino acids. This requirement is especially important at the time an infant is weaned and during the first few years of his growth. If balanced protein is absent, irreversible physical and mental stunting is likely to occur. Pregnant women and nursing mothers also need extra amounts of well-balanced protein.

The problem is further complicated by the fact that the great mass of hungry people are concentrated in the less developed countries lying in the tropical belt, where agricultural production and purchasing power are generally low. These are the countries whose rate of population growth is highest. About two thirds of the world's population now lives in this zone, and it is estimated that by the year 2000, the percentage will rise to 80.

About 50 percent of the people in these countries live in rural areas, and most of them are pitifully poor. The great majority live almost completely outside the money economy and have to grow what little they have to eat. Large numbers of urban poor in these areas also live marginally. Expensive protein sources like meat and animal products or synthetically enriched foods are not within the reach of either the subsistence farmer or the city slum dweller.

A major question facing world leadership is: <u>What can be done to reach these very poor people, especially in the less developed countries, and to help them improve the quantity and quality of their diets</u>? The argument is sometimes put forward that the economic and social pressures of the modern world, with its highly technological orientation, will ultimately force a discontinuance of subsistence or semi-subsistence farming. This viewpoint may in the end prove to be correct, but it is not a practical basis for action. For the immediate future, a great deal more must be attempted, along the lines of the Puebla Project,[1] to improve the lot

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[1] See <u>The Puebla Project 1967-69</u>, International Maize and Wheat Improvement Center, Mexico 6, D.F.

of the subsistence farmer and his family. If the quality of life of the small farmer is not improved substantially and rapidly, the present great influx of rural people into the slums of urban centers will continue to accelerate, with consequences in terms of human suffering and social dislocation and unrest that are already apparent.

Malnutrition and protein deficiency are on the increase among both urban and rural poor in the developing countries. According to recent World Health Organization figures, while the per capita production of the staple foodstuffs has remained stable, or may have increased slightly during the past two or three years, the per capita consumption of protein has declined on a worldwide basis - drastically so in many of the poorer countries, where protein deficiency disease, or kwashiorkor, is widespread.

The protein deficit is thus a crucial and worsening aspect of the total food problem, and it is going to be one of the most difficult to overcome.

At the present time, about 70 percent of the protein in the human diet worldwide comes from vegetable sources and 30 percent from animal sources. Table I shows the relative importance of the various products. The best prospect for increasing the availability of protein over the next ten years will undoubtedly be to increase production within all these traditional categories.

The spectacular progress made in recent years in increased production of rice, maize, and wheat has raised hopes that similar strides may be possible with other crops. The protein content of the major cereals ranges from about 8 to 16 percent, and there is hope that both the quality and quantity of their protein can be improved. The discovery of high-lysine corn in particular has opened new vistas in cereal breeding.[1] Geneticists hope to discover in other grains genes analogous to the opaque-2 and floury-2 genes in corn, permitting the development of crops having a

[1] In December, 1969, the United Nations Development Program made a grant of over $1.6 million to CIMMYT to strengthen international research and production programs on high-lysine corn.

In June, 1970, U.S. AID made available substantial support to Purdue University for a five-year program of research on the inheritance and improvement of protein quality of corn; this work is complementary to and linked with CIMMYT's efforts.

better balance of the eight amino acids that are essential for sound growth and health. Expanded and accelerated research to increase production and improve the nutritive quality of the major cereal crops is being undertaken at various centers as one main thrust toward overcoming protein deficits.

Another important approach is increasing meat production, especially beef production to utilize the rough forages that are now largely unutilized in the vast lowland tropics. This is still an almost completely neglected field, in which research and education should be fostered. Swine and poultry also undoubtedly have a greater potential in helping to overcome protein deficits in the tropical regions, as do fish products.

A drawback that must be taken into account, however, is the relatively high cost of animal products. Although they are considered the best protein source from the standpoint of amino acid balance and digestibility, they are out of the range of the poorest people. Protein from beef, the most expensive source, costs over 30 times as much as protein from soybeans, the cheapest. (Table II shows the cost of the major protein sources in human diets.)

Animal proteins have the additional drawback of being prohibited by religious laws in certain protein-deficit countries. Pork, for example, is forbidden to Moslems, and beef, to Hindus.

Synthesis of amino acids for enrichment of food products, as well as other approaches to providing additional protein through food processing and technology, must continue to receive attention. These sources, too, however, have disadvantages for use among very poor populations with strong traditional food habits - both cost and acceptance present difficulties.

As an approach to meeting the protein needs of the poor in the developing countries, the food legumes have many advantages. Besides being inexpensive, they are widely grown, accepted, and consumed worldwide. In many developing areas, they form a part of the staple diet - for example, beans in Latin America and dal of chick-pea, pigeon pea, mungbean, or lentil in India and Pakistan. They are used by all including the poorest people, and are often the only major protein component in their diet. These crops contain 18 to 25 percent protein (about double that in cereals), which closely resembles in quality and amino acid composition the protein from animal sources. In predominantly cereal diets, the legumes serve the important function of complementing the cereals in certain essential amino acids, to arrive at a good protein balance.

The U.S. President's Science Advisory Committee, reporting on The World Food Problem, stressed the importance of increasing and improving protein supplies from indigenous products in the developing countries, and pointed out specifically the need to "increase the production and use of pulses and oil seeds such as soybeans, peanuts, and cottonseed."[1]

Several authoritative bodies have likewise signaled the potential importance of the food legumes. The Food and Agriculture Organization of the United Nations recently developed an Indicative World Plan for Agricultural Development that identified major issues likely to be facing agriculture in the 1970's and early 1980's. This Plan emphasizes the urgent need to bridge the protein gap by working at the problem from all possible angles, one of the most important being to increase production of high-protein crops such as peanuts, soybeans, and certain grain legumes, as well as to breed higher protein varieties of root crops such as sweet potatoes and yams. The FAO points out further that "In Asia and Africa, taken as a whole, pulses provide a greater direct contribution to the total quantity of protein in the human diet than do the livestock and fishery sectors combined, and will continue to do so throughout the Plan period."[2]

The Protein Advisory Group, sponsored by WHO, FAO, and UNICEF, issued a statement in the spring of 1970, which included the recommendation that "more attention be given in agricultural programmes to the use of crop varieties having potential for higher amounts and quality of protein. These should include not only cereals but also grain legumes..."[3]

With a few exceptions, the food legumes have not benefited from research and production programs. A look at world acreage, production, and yield figures for all the major food crops reveals that the legumes are far behind in yield per hectare, although the total acreage devoted to them is relatively high, reflecting their importance. (See Table III and Table IV.)

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[1] The World Food Problem, A Report of the President's Science Advisory Committee, The White House, May, 1967, Vol. I, p. 26.

[2] Provisional Indicative World Plan for Agricultural Development, Food and Agriculture Organization of the United Nations, August, 1969, Vol. 1, p. 84.

[3] PAG Statement on Plant Improvement by Genetic Means, the FAO/WHO/UNICEF Protein Advisory Group. Statement following its 17th meeting in New York 25-28 May, 1970.

With the exception of such crops as beans (Phaseolus vulgaris), peas (Pisum spp.), peanuts (Arachis hypogaea), and soybean (Glycine max), which are of importance in the developed world, the majority of the food legumes are of importance only to the people of developing countries. They have had little economic value as cash crops or as exports, because utilization has been almost solely confined to immediate home consumption, or at best to close-range, farm-to-consumer marketing. As a result, these crops have not attracted attention in improvement programs, in contrast with wheat, rice, or maize, which have always had worldwide importance.

The amount of research done on the food legumes has therefore been very limited, the information base is low, and experienced research workers are few. Production levels remain low because of the inherent characteristics of the varieties grown, damage from diseases and insect pests, and poor cultural practices.

An immediate, substantive impact on improvement of these crops is clearly necessary. Programs must be designed so as to require a minimum of cultural adjustment in respect to crop management, food habits, and preparational procedures. These conditions dictate a careful selection among a few widely adapted and accepted species for intensive work, and the kind of problem-solving investigations most directly applicable to peasant agriculture.

Diversity of the Food Legume Crops

About 20 species of food legume crops are used in appreciable quantities in the human diet in one part or another of the world. All of them belong to the botanical family Leguminosae (the pea or bean family), which includes more than 10,000 species ranging from tiny wild vetches to large perennial trees. Table V lists the important species used for human consumption and indicates the general areas of production, geographical and ecological zones of adaptation, crop habits, and reported yields.

Among the major food legume crops, production and utilization is often highly regionalized. Table IV shows the world production of these crops by regions.

Recommendation as to the Priority of Food Legume Crops on which Initial Increased Effort Should Be Focused

Since it would be impractical and unfeasible to attempt to accelerate research on all 20 of the food legume crops simultaneously, it is recommended that six species be given primary attention, in the following order of priority: 1) dry beans; 2) cowpeas; 3) pigeon peas; 4) chick-peas; 5) soybeans; 6) peanuts. As a practical approach, these crops can be grouped according to the following ecological regions of adaptation:

A. Low humid tropics[1]
   1. Pigeon peas (*Cajanus cajan*)
   2. Cowpeas (*Vigna sinensis*)

B. Semidry or seasonal tropics
   3. Peanuts (*Arachis hypogaea*)

C. Tropical intermediate elevations to temperate zones
   4. Soybeans (*Glycine max*)
   5. Beans (*Phaseolus vulgaris*)

D. Cool-weather, high-elevation zone
   6. Chick-peas (*Cicer arietinum*)

The above six crops are selected for initial concentrated attention on the basis of their present importance in terms of acreage and production combined with what the writer considers as their possible potential importance in helping to bridge the protein gap.

The selection of these six crops for initial accelerated research efforts is not intended to imply that the others should be ignored. Several of the other food legume crops also undoubtedly merit increased attention, and it is hoped that this will be forthcoming as additional resources become available to strengthen and expand investigations on them at major international research centers and/or in national institutions where research on them is either already under way or can be efficaciously established.

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[1] It is recognized that the ecological definition of regions of adaptation of the different crops is somewhat arbitrary. For example, pigeon pea, while adapting quite well to the low, humid tropics, is also adapted to dry, cool conditions, especially during a certain stage of its growth, as long as there are no frosts. Similar qualifications could be made with respect to the ecological conditions of prime adaptation of some of the other five crops listed here.

Recommended Approach to Expanding and Accelerating Research on the Six Selected Food Legume Crops

It is recommended that responsibility for in-depth research and certain training and information services on the selected crops be assumed either by international institutes now in existence or by an upland-crops center that is being contemplated for establishment, as follows:

1. Dry bean - International Center of Tropical Agriculture (CIAT), Palmira, Colombia;
2. Cowpea - International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria;

CIAT and IITA from the beginning have planned research work on the food legumes as important components of their core programs. CIAT has budgeted approximately $200,000 and IITA, about $136,000 to support their programs on food legumes in 1971. These amounts will enable these two centers to launch solid initial efforts to improve one food legume crop each, although some additional funds will be required as the work expands. IITA has indicated strong interest in the cowpea and CIAT, in the dry bean.

3. Pigeon pea - an upland-crops center, CIAT, or IITA;
4. Chick-pea - an upland-crops center or the International Maize and Wheat Improvement Center (CIMMYT), Chapingo, Mexico;

If an international institute concerned with upland agriculture, placing emphasis on dryland crops such as sorghums and millets, should be established soon somewhere in South or Southeast Asia, it is recommended that the international center responsibility for pigeon peas and chick-peas be assigned to it.

If such an institute is not created, it is recommended that the responsibility for pigeon pea be assumed either by CIAT or IITA and that for chick-pea, by CIMMYT.

Since both IITA and CIAT are in the process of planning their programs on the food legume crops, the final decision as to which center should assume responsibility for pigeon peas can best be postponed until their plans are crystallized.

The basic charter of CIMMYT permits it to undertake work on other crops in addition to maize and wheat, if in the view of its board of directors expansion of its activities is justified and if, of course, additional funds are made available to finance such expansion.

5. Soybean - CIAT or IITA;
6. Peanut - A strong possibility for the location of center responsibilities for peanuts would be IITA. There may be other alternatives. Before a definitive selection can be made, additional studies will be necessary.

In arriving at the conclusion on which this recommendation is based, many factors were weighed. First, a major question that had to be dealt with was whether it would be advantageous to create a new autonomous international institute, along the lines of the International Rice Research Institute in the Philippines or the International Maize and Wheat Improvement Center in Mexico, to assume the international center responsibilities for all activity connected with work on the food legume crops, those initially selected for top priority as well as others that may be added in the future. The principal pros and cons are the following:

Pros

1. It would serve to give the legume crops additional stature in the family of man's important food crops and would elevate them from their present status as "step-children" in this family.
2. Concentration of resources, facilities, and scientific talent in one location would tend to maximize the coordination of research, training, and information services on all of the crops being worked on. More synergism could be expected under such circumstances.

Cons

1. There is a very wide range in the ecological conditions of adaptation among the food legume species. If improvements comparable to those that have been obtained in the cereals are to be achieved in the food legume crops, each

of the major species must be treated as an entity. As with the cereals, each crop species has its own unique set of characteristics and problems and its own ecological setting of adaptation. There is no more similarity between chick-peas and pigeon peas, for example, than between wheat and rice, and therefore there would be no more justification to concentrating improvement efforts on all food legume crops in one international food legume research institute than there was to combining the international research programs for wheat and rice in one institute.

2. International institutes like IRRI, CIMMYT, CIAT, and IITA are expensive to mount and to operate and complex in their management. Administrative and overhead costs for each of these probably amount to a million dollars or more per year regardless of their program content. Introducing additional crop programs into an existing institute would thus provide the advantage of economy of scale; in weighing this factor, however, it is important to examine the effect that added responsibilities would have on the total program and the attainment of the desired objectives. Consideration must be given to the feasibility of the existing institute successfully taking on additional programs without danger that its present programs would suffer from diffusion and dilution of resources and efforts.

It would appear that these conditions could be met satisfactorily by assigning the center responsibilities for the six selected food legume crops to IITA, CIAT, CIMMYT, or an upland-crops institute contemplated for establishment in South or Southeast Asia, as recommended, provided, of course, that sufficient additional funds were made available to cover fully the expenses of these new programs. It would be possible to achieve a high quantitative and qualitative level of work on these crops and to do this at a substantial economic saving, if this recommendation is followed. It is a sine qua non that the autonomous institutes involved enthusiastically back this plan, if it is to work effectively.

Rationale for the Assignment of the Crops
to the Specific International Institutes as Recommended

1. Dry beans to CIAT:

Dry beans originated in Latin America: they are produced and consumed in greater quantities there than in any other region of the world. Furthermore, there are more good national bean improvement programs now under way in Latin America than anywhere else.

2. Cowpeas to IITA:

Cowpeas originated in Africa, and consequently it is in this region that the greatest range of genetic diversity in this crop is to be found. Africa accounts for more than 90 percent of the world's cowpea production, and, overall, the cowpea is by far the most important food legume in the diet of the Africans south of the Sahara.

3. Pigeon peas to CIAT:

As stated earlier, the first choice of location for the international center for research on this crop would be India, where more than 90 percent of the world's pigeon peas are produced. If a new international center for upland agriculture is not created in that country or in the surrounding region in the next year or so, it is recommended that the international center responsibilities for this crop be assigned to either CIAT or IITA. From the ecological standpoint, CIAT is well located to handle it. Since both are planning a major thrust on food legumes, either should be able to take on responsibility for three crops without overloading itself in the program sector - provided, of course, that adequate funds and staff are made available. Both CIAT and IITA already have plenty of land to accommodate these crops, but modest additional capital investment would be required for equipment at either center.

4. Chick-peas to CIMMYT:

India would also be the first choice as a location for work on chick-peas; but if an international institute for upland agriculture is not created within a reasonable period of time in that country or in the surrounding region, it is recommended that center responsibilities for this crop be assigned to CIMMYT. Chick-peas grow well at the higher elevations of the large central plateau of Mexico, the Bajío. Mexico has been a traditional producer of chick-peas on a significant scale for many years, and on occasion even exports a small quantity to Europe. CIMMYT could add work on chick-peas to its crop programs with a minimum of difficulty and only modest additional cost.

5. Soybeans to CIAT or IITA:

Soybeans are rapidly increasing in importance in Latin America, especially in Brazil and Colombia. Brazil is now in third position in world soybean production, after the United States and Mainland China. CIAT is very favorably situated to work on this crop, both from ecological and geographical standpoints. It will have several national soybean improvement programs in the Latin American region with which to collaborate, and the relative nearness of CIAT to the United States will facilitate close linkages with the U.S. Department of Agriculture and several state experimental stations that are world leaders in soybean research.

While soybeans are not yet grown to an appreciable extent in Africa, there is an increasing interest in them in several places on that continent. IITA should also be able to effectively assume the center responsibilities for this crop. Both CIAT and IITA are now in the initial stage of planning their programs on the food legumes, and they are jointly determining the rational division of labor and responsibilities, including which center will concentrate on which crops. It is recommended, therefore, that the final decision as to which of these two centers should assume the major responsibility for this crop be postponed until the feasibility studies now under way by them are completed.

6. Peanuts to IITA as a strong possibility:

Although peanuts are native to South America, they have become the second most important food legume crop in sub-Sahara Africa since they were introduced on that continent more than 400 years ago. Nigeria is an especially important producer of peanuts (about 800,000 metric tons annually) as are Senegal and some of the other countries in West Africa, where IITA is situated.

In addition to the fact that IITA is located in an important peanut-producing region, other factors favor IITA's assuming the center responsibilities for this crop. Research on food legumes has been planned from the start as an important component in IITA's overall program. The question which IITA is now studying is how many of these crops, and which ones, it should concentrate on. It could probably handle at least two and perhaps three, if provided the necessary support, and by doing so would reduce overhead and other costs per crop. IITA may decide, however, after completing its present feasibility study on the food legume crops, that it should not or could not assume the center responsibilities for peanuts. If this should happen, it is recommended that a broad and thorough feasibility study be made to determine how and where an effective international improvement program on peanuts can best be mounted.

The Role of a Center in Worldwide Networks of Institutions Concerned with Improving the Different Major Food Legume Crops

The International Rice Research Institute and the International Maize and Wheat Improvement Center serve as good examples of the kinds of functions and activities that international centers can perform to help increase the production and yield of selected crops on a worldwide scale.

In organizing work on the principal food legumes, the goal is the creation for each crop of a worldwide network that would link three components:

1. all of the national institutions of the developing countries that have improvement programs on a particular crop and wish to collaborate in such an international network: these programs constitute the principal pillars of the network and have basic responsibility for improving a specific crop in their respective countries;
2. an international center that serves as a primary force to draw the network together and as a catalyst within the network: its principal objective is to help strengthen national programs and institutions in the developing countries by performing certain functions, of which the main ones will be described below;
3. national institutions in the developed countries that have very valuable scientific and technological resources, which are not now being utilized nearly as effectively as they

might be to help improve the yields and quality of the major food legume crops in the less developed regions of the world.

International Center Responsibilities and Functions

To achieve its main goals of strengthening national programs in the developing countries, increasing yields of the crop or crops for which it assumes responsibility, and improving the nutritive quality of those crops, the international center would perform the following principal functions:

1. Complete the collection and evaluation of the world germplasm;

   In none of the six crops recommended for expanded research attention has this job been more than partially completed. For dry beans, soybeans, and peanuts, it has been done more completely than for the other three crops, but even for these three there is still much to be done. The U.S. Department of Agriculture germplasm collections for some of the food legume crops are probably as large as those of any organization. Many of these were assembled by the Department's U.S. AID-supported programs to improve several of the food legume crops in India and Iran, in collaboration with scientists and institutions in those countries. In these germplasm collections there are approximately 26,000 entries representing ten species. The Department is now increasing the seed of these collections, some in collaboration with CIAT, IITA, and the Colombian Institute of Agriculture (ICA) so that these can be made available right away to the breeders around the world who may be interested in evaluating them. This is a good start, but only a start.

   Scattered here and there in institutions around the world, there are partial collections of germplasm of each of the various crops. An international center can perform no more vital function than to bring together all of the existing material and complete this assembly of germplasm through additional systematic collection; in addition to completing the collection of cultivated and primitive varieties, particular attention should be given to bringing together the related wild species, which may carry valuable genes for specific traits such as drought or frost resistance, salinity tolerance, or resistance to diseases and insects.

Once this material is assembled, it must be carefully grown and exhaustively evaluated; all data must be catalogued and published, and seed supplies maintained in viable condition and sufficient quantities to be available for distribution to anyone who may wish to use it anywhere in the world. This is a formidable task for the international centers that take on these crops, but it is the most basic service a center can render. Completing the collections of germplasm will represent a considerable expense - a point I shall take up later on.

2. <u>Conduct certain kinds of research focused on increasing yields and improving quality</u>;

International centers would concentrate on problems of worldwide or regional importance, such as increasing yields and improving quality. Principal activities, which would require a tightly knit interdisciplinary team effort with close collaboration among plant breeders, plant physiologists, entomologists, pathologists, agronomists, and biochemists, would include the following:

a) Breeding for inherent yielding ability: In the food legumes, little is known of the inherent potential for high yield. It has often been stated that the maximum yield potential of legume crops is considerably lower than that of cereals, and this may be so. We do not know whether it is or not. The reported yields of pigeon peas in excess of 5,000 kg/hectare obtained in India using an already existing local variety but with good cultural practices of fertilizer, pest control, plant populations, etc., indicate the possibility of considerable improvement if not of dramatic breakthroughs.

It is of great importance to obtain sound information on yield potentials by doing in-depth research on plant size, plant shape, and leaf size, shape, and location, all in relation to incident sunlight and photosynthetic efficiency, by studying advanced breeding lines and potential varieties for response to fertilizer and irrigation, for rapid germinating seed and seedling vigor, and for the ability of their root systems to utilize moisture and nutrients. It is important to breed types with heavy flowering potential and fruiting efficiency as well as types with high potential in other components of yield such as pod size, seed size, seeds per pod, and non-shattering habit, to facilitate harvest and minimize field losses.

b) Breeding for improved quality: Next to achieving an improved crop yielding ability, which in itself provides a greater production of protein, a most important consideration is improving the protein, both quantitatively and qualitatively. Preliminary screening of germplasm collections at various institutions has shown considerable variation in total crude protein (for example, 18-32 percent among 1,800 germplasm lines of pigeon peas screened in India).

The germplasm collections and advanced breeding materials should be systematically analyzed for total protein, different amino acids in which the food legumes are deficient, and for reduced content or total absence of various antimetabolites and toxic factors.

Rapid screening techniques for several of these factors must be developed to permit analysis of large numbers of samples.

Attention should also be given to processing characteristics and consumer acceptance qualities such as cooking ability (length of time for cooking in relation to requirements of scarce fuels), taste, flavor, and preservation of nutritive value with storage, processing, home cooking, and food preparation.

c) Breeding for resistance to diseases and insect pests: Diseases have been the most serious factor in limiting yields of food legumes. The safest and most economical method of control, and perhaps the only practical method for the developing countries, is the use of resistant varieties.

Insects are also of major importance in legumes, both as vectors of diseases and through direct damage in field and storage. Again the most economical means of control is through inherent resistance.

Development of both disease and insect resistance requires collaboration of plant breeders, pathologists, and entomologists in screening of germplasm and breeding material both under natural field conditions and in a controlled environment.

d) Breeding for maximum tolerance to adverse conditions: As most of the world's agricultural land is subject to one or more factors that limit crop production, it is of considerable importance that new varieties incorporate such characteristics as drought tolerance or in some cases tolerance to prolonged periods of flooding; salinity tolerance; frost resistance; tolerance to soil nutrient deficiencies and other environmental stresses.

e) Broad crosses: The almost universal weakness of present improvement programs in the various food legume crops is their narrow genetic base. It is essential that new sources of genetic variability be introduced in breeding programs for all characters for which improvement is sought.

Crosses should be made involving parental stocks widely different in areas of origin, plant characteristics, disease and insect resistance, reaction to flooding, drought, salinity, frost, etc. These should include intraspecific crosses (between parents belonging to the same species), interspecific crosses (between parents belonging to the same genus but different species; many wild types of chick-peas, for example, belong to different species of the genus *Cicer*), and even intergeneric crosses.

Obtaining successful, viable plants from such crosses will often require highly sophisticated laboratory techniques such as embryo and tissue culture, for which collaboration between the centers and other institutions which have special competence and skills in these fields may be needed.

f) Soil and crop management: Research should be conducted to determine soil and crop management practices, particularly for new types and varieties as they are developed. This would include studies of factors affecting the differential capacity of varieties to utilize soil resources, withstand deficiencies, utilize and absorb inherent soil nutrients or applied fertilizers, tolerate salinity, penetrate hard or poorly aerated soils, etc.

Studies should be made of cropping sequences, plant populations, times and rate of planting, fertilizer applications. Of considerable importance are studies to determine the maximum yield potential and the factors involved, such as photosynthetic activity in relation to plant type and plant populations, root development of different genotypes under different conditions of soil types, moisture conditions, fertility levels, and other environmental conditions.

g) Increasing the efficiency of rhizobium bacteria in symbiotic relationships with the food legumes: Rhizobium species are quite specific in their ability to serve as effective nitrogen fixation agents for specific legume crops. They differ in their ability to fix nitrogen in relation to their initial concentration, genetic constitutions, host-plant species, and a number of environmental factors such as temperature, moisture, soil type, soil acidity, nutrient availability, presence of competing bacteria in the soil, etc. Thorough studies in this field are important to obtain maximum benefit from a source of naturally available nitrogen which is most efficiently utilized by legumes and which eliminates the need for expensive nitrogen fertilizers.

h) Disease control: Surveys must be conducted to determine the most important diseases, identify pathogens and their races, and study the epidemiology, vector relationships, and life histories of pathogens. The causal organisms for many diseases of food legumes, although they have seriously reduced yields for many years, have not as yet been identified.

Although varietal resistance offers the most reliable and economic control of most diseases and pests, other methods should be investigated. These include the use of chemicals such as fungicides; the relationships between cultural practices such as planting dates, plant populations, moisture control, and crop rotations on disease incidence; and insect control in relation to occurrence and spread of diseases (vector-virus relationships).

i) Insect control: In addition to screening for genetic resistance, studies must be conducted to develop information on the biology, ecology, and population dynamics of the major insect pests. Major emphasis in the chemical-control portion of the research program will be on the development of methods for utilizing safe and nonpersistent chemicals and on the design of integrated control programs.

3. Offer professional training;

Training of carefully selected professionals from the various collaborating institutions in the countries around the world should be offered, both through in-service internships and through longer-term learning experiences leading to advanced degrees. The latter would be accomplished through arrangements between the center and universities with which it collaborates.

4. Provide information and documentation services;

5. Organize conferences, symposia, and workshops;

6. Arrange for the exchange of materials and research results;

This would be facilitated through routine and frequent visits of center staff to collaborating institutions and programs.

7. Conduct comparative tests and maximum yield trials;

In collaboration with the other institutions in the global network, the centers should conduct comparative uniform tests for yield and for disease and insect resistance. They should also stimulate trials to determine the maximum biological yield ceiling of each crop.

8. Provide direct support to national programs when requested to do so, if special funds are available to support the work.

Projects of Common Interest that Should Be Jointly Undertaken by the International Centers Involved

1. Collection of germplasm;

Since many regions and countries have several food legumes in common (for example, all crops considered are grown in India), it is important that work on systematic collection of the world's germplasm of these crops be done on a well-coordinated and closely collaborative basis. This will avoid duplication of efforts by the major research centers and by national programs, increase the efficiency of exploration and collection teams, and reduce costs.

As soon as possible, a workshop conference should be planned to bring together representatives from CIAT, IITA, CIMMYT, USDA, FAO, and other agencies, as well as specialists from the United Kingdom, France, India, and other countries, who have knowledge and competence in this field, to plan the future collecting work. A steering committee should be formed at this meeting to plan and coordinate the activities.

Exploration and collection trips should be scheduled so as to permit as many species as possible to be obtained simultaneously.

To avoid the introduction of seed-borne fungi and viruses, it may be necessary to establish a central location for initial growing and screening of the collected material before transfer of the seed to the respective international centers.

It will probably take from two to three years to complete this work. There is no way to make a meaningful estimate of costs involved, but it is likely that somewhere between $250,000 and $500,000 will be required.

2. Research on nutritive quality;

Many species of food legumes have certain aspects of nutritive quality in common. They are almost universally deficient in the sulfur amino acids, particularly methionine and cystine, and some are deficient in tryptophan.[1] Also common to many of these crops are certain toxic factors, antimetabolites such as trypsin inhibitors, and flatus-producing factors which present problems in their utilization as foods. Current knowledge about many of these factors has been well summarized in a recent book, Toxic Constituents of Plant Foodstuffs, by Irvin E. Liener, et al.

Much research will be needed to arrive at an understanding of these problems and their solutions. This will require a very high level of specialized scientific competence, particularly in biochemistry, as well as sophisticated, costly equipment. It is therefore recommended that work of this nature not be attempted at the three centers, but that they get together, with consultants if necessary, to determine what kinds of research along this line should be farmed out to institutions and individuals in the developed countries

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[1] See Table VI, p. 37 for amino-acid content of the major food legumes.

where this work can best be done. It would be highly desirable to hold a workshop meeting that would bring together representatives of the three centers and a small group of leading world scientists in this field, to treat this subject and to make concrete plans for coordinated and collaborative research action.

This approach should be followed in dealing with other basic research problems that may be encountered in different fields. The vast reservoir of scientific expertise that exists around the world and especially in the developed countries should be tapped to the fullest extent possible in seeking the solutions to the problems that present barriers to increasing the yields of the food legume crops and improving their quality and utilization.

Staffing Requirements of an International Center

The central research staff should consist of an interdisciplinary, international team of highly qualified scientists that would provide essential capabilities in areas where major breakthroughs are considered essential - breeding, physiology, pathology, entomology, agronomy, and biochemistry.

To illustrate more specifically the recommended staff composition of such an interdisciplinary team at one of the centers, CIAT will be used as an example. CIAT would need three plant breeders, one to concentrate on each of the three crops for which it would be responsible. One of these breeders could be made coordinator of the interdisciplinary team on food legumes. Each plant breeder should have an assistant plant breeder, as well as the necessary laboratory and field technicians. In addition, the team should have one physiologist, one pathologist, one entomologist, one agronomist, and one biochemist. Each of these scientists would have responsibility for more than one crop and therefore should have technically competent assistants in addition to the normal complement of laboratory technicians.

The composition of the teams at IITA and CIMMYT would be the same, except that they would have two plant breeders plus two assistant plant breeders, and one plant breeder plus one assistant breeder, respectively.

Because of the importance of training in this program, adequate provision must be made for the assignment of graduate assistants and interns in each field.

The chart on page 23 shows the recommended staffing pattern for each international center along with approximate budget estimates for the initial stages of the program. These are presented as rough estimates only, with the aim of giving a general idea of the minimum size of the interdisciplinary teams, and the annual operating budgets needed to support them, that would be required for effective implementation of the general recommendations made in this report. These estimates are of course subject to modification and refinement as more detailed planning is done and decisions are made with respect to alternatives.

It can be argued, for example, that each crop should have its own complete interdisciplinary team, regardless of whether two or more crops are centered at one location, so that the staff would not be too thinly spread; that the teams should perhaps vary in their disciplinary composition from crop to crop, depending on the nature and relative importance of the problems to be dealt with in each crop, etc. The validity of such arguments is recognized.

However, after weighing the many factors that must be taken into account in the overall picture - for example, restrictions on funding and the problem of setting priorities for the use of limited research funds on food legume crops vis-à-vis other more important food crops such as the major cereals - the author has arrived at the recommendations pertaining to staffing and budget that are presented here.

Presenting these recommendations in the manner shown in the following chart is not intended in any way to prejudice future decisions that still must be made with regard to center locations for the different crops. For example, three crops are shown for CIAT and two for IITA. In the final outcome, this may be reversed. A main objective of this tabular presentation is to give an example of the staff patterns and budgets that would be necessary to support work at a given center (whether at IITA, CIAT, the upland-crops institute, or CIMMYT) if it undertook a single crop program or two or three.

Recommended Staffing Patterns and Estimated Budgets

Salaries and Perquisites	CIAT Dry Beans Soybeans Pigeon Peas	IITA Cowpeas Peanuts	CIMMYT Chick-peas
Position			
Plant Breeder - Dry Beans	$ 30,000		
" " - Soybeans	30,000		
" " - Pigeon Peas	30,000		
" " - Cowpeas		$ 30,000	
" " - Peanuts		30,000	
" " - Chick-peas			$ 30,000
Ass't			
Plant Breeder - Dry Beans	10,000		
" " - Soybeans	10,000		
" " - Pigeon Peas	10,000		
" " - Cowpeas		10,000	
" " - Peanuts		10,000	
" " - Chick-peas			10,000
Physiologist	30,000	30,000	30,000
Ass't Physiologist	10,000	10,000	10,000
Pathologist	30,000	30,000	30,000
Ass't Pathologist	10,000	10,000	10,000
Entomologist	30,000	30,000	30,000
Ass't Entomologist	10,000	10,000	10,000
Agronomist	30,000	30,000	30,000
Ass't Agronomist	10,000	10,000	10,000
Biochemist	30,000	30,000	30,000
Ass't Biochemist	10,000	10,000	10,000

Recommended Staffing Patterns and Estimated Budgets (continued)

	CIAT		IITA		CIMMYT	
Research Assistants and Technicians						
Plant Breeding	(2)	$ 4,000	(1)	$ 2,000	(1)	$ 2,000
Physiology	(2)	4,000	(1)	2,000	(1)	2,000
Pathology	(2)	4,000	(1)	2,000	(1)	2,000
Entomology	(2)	4,000	(1)	2,000	(1)	2,000
Agronomy	(2)	4,000	(1)	2,000	(1)	2,000
Biochemistry	(2)	4,000	(1)	2,000	(1)	2,000
Graduate Interns	(3)	6,000	(2)	4,000	(2)	4,000
Secretaries	(2)	6,000	(1)	3,000	(1)	3,000
Field Foremen	(2)	5,000	(1)	2,500	(1)	2,500
Laborers	(5)	10,000	(3)	6,000	(2)	4,000
Hourly help and overtime		2,000		1,500		1,000
Total Salaries		$373,000		$309,000		$266,500
Other Expenses						
Supplies		50,000		30,000		20,000
Transportation		6,000		4,000		2,000
Maintenance		6,000		4,000		2,000
Travel		30,000		20,000		10,000
Training		75,000		50,000		25,000
Total Other Expenses		$167,000		$108,000		$ 59,000
Overhead and Miscellaneous Expenses (30%)		162,000		125,100		97,650
Grand Total		$702,000		$542,100		$423,150

Needs for Additional Capital Development Funds

By assigning the center responsibilities for the six major crops to IITA, CIAT, and CIMMYT, the total amount of capital funds that would be needed would be quite modest in comparison with the amount that would be required if a new international institute for food legumes were to be created. Basic needs for land, office and laboratory space, and equipment for food legume research programs at both CIAT and IITA have already been provided by the original capital development grants for the establishment of these two institutions. To expand and accelerate these programs as recommended at IITA and CIAT would necessitate some additional laboratory space and equipment at both centers. It is estimated that approximately $300,000 for each would cover these needs.

The capital-fund needs for CIMMYT would be somewhat greater, even though it would be working with only one food legume crop, chick-peas. The total provision for land, office and laboratory space, and equipment would be required to enable this Center to take on the responsibility for this crop, and it is estimated that between $400,000 and $500,000 would be needed for this purpose. The total amount of capital funds needed for the three centers would be about $1 million.

Continuity of Effort, a Prime Requisite for Success

Implementation of the recommendations contained herein should be undertaken only if the potential international supporting agencies are firmly committed to provide the financial backing that will be needed for a minimum period of 15 years. While there are several important factors involved in determining the degree of success such programs will have, none are more important than stability and continuity of effort over a long enough period to permit the achievement of substantial results and to make a significant impact on improving these vitally important protein-rich crops.

LIST OF TABLES

Table I. Present Sources of Protein in the Human Diet . . . 27

Table II. Cost of Major Protein Sources in Human Diets . . . 27

Table III. World Acreage, Production and Yield of Certain Crops. 28

Table IV. World Production of Pulses 29

Table V. Important Legumes Grown in the Tropics and Subtropics 33

Table VI. Amino-Acid Content of Legumes. 37

Table I. Present Sources of Protein in the Human Diet*

From animal sources		- 29%
Meat and poultry	- 13%	
Dairy products	- 11%	
Eggs	- 2%	
Fish	- 3%	
From vegetable sources		- 71%
Grains	- 50%	
Pulses, oilseeds and nuts	- 13%	
Vegetables and fruits	- 3%	
Starchy roots	- 5%	

Table II. Cost of Major Protein Sources in Human Diets**

Source	U.S.$/lb.	% Protein	U.S.$/lb. protein
Beef	.70	15.2	4.60
Pork	.50	11.6	4.30
Poultry	.30	20.0	1.50
Nonfat dry milk solids	.145	35.6	.41
Dry beans	.08	23.1	.35
Soybeans	.05	34.9	.14

* The State of Food and Agriculture 1964, Food and Agriculture Organization of the United Nations, pp. 108-109. (The percentages represent worldwide protein consumption.)

** Dimler, R.J., "Soybean Protein Foods," Soybean Protein Foods 166, Agricultural Research Service, U. S. Department of Agriculture 71-35, May, 1967. (The costs are based on average United States values.)

Table III. World Acreage, Production and Yield of Certain Crops

	World Acreage (Hectares) 1968	World Yield (Kg/hectare) 1968	World Production (Metric Tons) 1968
Cereal Grains			
Wheat	227,500,000	1,460	332,500,000
Rice (Paddy)	132,200,000	2,150	284,200,000
Maize	106,000,000	2,370	251,100,000
Millet and Sorghum	111,200,000	770	85,100,000
Barley	74,900,000	1,740	130,700,000
Oats	32,300,000	1,680	54,200,000
Rye	22,400,000	1,500	33,400,000
Root Crops			
Potatoes	22,800,000	13,800	315,500,000
Sweet Potatoes and Yams	16,000,000	8,400	134,400,000
Cassava	9,794,000	8,700	85,625,000
Sugar Beets	7,875,000	31,900	251,244,000
Legumes			
Soybeans	33,566,000	1,300	43,613,000
Pigeon Peas	2,895,000	630	1,829,000
Dry Beans	22,686,000	470	10,708,000
Groundnuts (in Shell)	17,620,000	850	15,034,000
Chick-peas	10,844,000	690	7,445,000
Cowpeas	2,810,000	390	1,083,000

Source: 1969 Production Yearbook, Volume 23, Food and Agriculture Organization.

Table IV.
World Production of Pulses

Region	Dry beans	Chick-peas	Pigeon peas	Cow-peas	Dry peas	Lentils	Dry broad beans	Other pulses	Total	% of Total
FAR EAST (1)										
Area	8,365	9,539	2,751	42	1,054	899	9	3,577	26,236	41.8
Prod.	2,619	6,558	1,760	26	970	458	11	1,710	14,112	33.0
Yield	310	690	640	620	920	510	1,220	478		
(India and Pakistan)										
Area	(7,591)	(9,439)	(2,671)		(1,029)	(899)		(2,867)	(24,496)	(39.1)
Prod.	(1,969)	(6,500)	(1,745)		(950)	(458)		(1,285)	(12,907)	(30.2)
Yield	(259)	(689)	(653)		(920)	(509)		(450)		
NEAR EAST										
Area	177	227		13	4	291	219	401	1,332	2.1
Prod.	195	206		16	7	223	328	383	1,357	3.2
Yield	1,100	910		1,230	1,750	770	1,500	955		
AFRICA										
Area	1,334	505	100	2,698	485	216	413	1,837	7,588	12.1
Prod.	805	316	38	1,004	352	128	341	891	3,875	9.1
Yield	600	630	380	370	730	590	830	485		
EUROPE										
Area	3,446	366		11	452	90	678	688	5,731	9.1
Prod.	800	215		9	529	60	767	613	2,993	7.0
Yield	230	590		820	1,170	670	1,130	891		
NORTH AMERICA										
Area	545			40	121	25			731	1.1
Prod.	833			25	197	31			1,086	2.3
Yield	1,530			630	1,630	1,240				
LATIN AMERICA										
Area	6,782	207	44		147	37	318	37	7,572	12.1
Prod.	4,003	150	31		101	22	189	33	4,529	10.6
Yield	590	720	700		690	590	590	892		

Table IV. World Production of Pulses (continued)

Region	Dry beans	Chick-peas	Pigeon peas	Cow-peas	Dry peas	Lentils	Dry broad beans	Other pulses	Total	% of Total
OCEANIA										
Area	2			6	29				37	.05
Prod.	1			3	41				45	.10
Yield	600			530	1,410		950			
MAINLAND CHINA										
Area	2,000F				3,400F		3,050F		8,450	13.5
Prod.	1,390F				3,100F		3,000F		7,490	17.5
Yield	700F				910F		980F			
USSR										
Area	35				3,137	56		1,824	5,052	8.1
Prod.	62				4,818	74		2,258	7,212	16.9
Yield	1,770				1,540	1,320		1,238		
WORLD TOTAL										
Area	22,686	10,844	2,895	2,810	8,829	1,614	4,687	8,364	62,729	
Prod.	10,708	7,445	1,829	1,083	10,115	996	4,636	5,888	42,700	
Yield	470	690	630	390	1,150	620	990	704		
% of Total										
Area	36.2	17.3	4.6	4.5	14.1	2.6	7.5	13.3		
Prod.	25.1	17.4	4.3	2.5	23.7	2.3	10.9	13.8		

Area = 1000 Hectares
Production = 1000 Metric Tons
Yield = KG/Hectare

F = FAO Estimate
(1) Including India and Pakistan

Dry beans (Phaseolus vulgaris, P. lunatus, P. aureus, P. radiatus, P. mungo, and P. angularis)
Chick-peas (Cicer arietinum)
Pigeon peas (Cajanus spp.)
Cowpeas (Vigna sinensis)
Dry peas (Pisum sativum and P. arvense)
Lentils (Lens esculenta or Ervum lens)
Dry broad beans (Vicia faba)
Other pulses (Dolichos spp., Lathyrus spp., Voandzeia subterranea, Trigonella foenum graecum, etc.) and including Vetch (Vicia sativa) and Lupins (Lupins spp.)

1968 figures from 1969 Production Yearbook, Volume 23, Food and Agriculture Organization

Table IV.

World Production of Soybeans and Groundnuts[1]

Region	Soybeans	% of Total	Groundnuts in Shell	% of Total
FAR EAST (2)				
Area	1,654	4.93	8,412	47.74
Prod.	1,161	2.67	5,869	39.03
Yield	700		700	
(India and Pakistan)				
Area			(7,160)	(40.63)
Prod.			(4,582)	(30.47)
Yield			(640)	
NEAR EAST				
Area	8	.02	372	2.11
Prod.	9	.02	292	1.94
Yield	1,130		780	
AFRICA				
Area	30	.09	5,225	29.65
Prod.	23	.05	4,219	28.06
Yield	770		810	
EUROPE				
Area	54	.16	14	.07
Prod.	50	.11	22	.14
Yield	930		1,570	
NORTH AMERICA				
Area	16,753	49.91	581	3.29
Prod.	30,269	69.40	1,153	7.66
Yield	1,810		1,980	
LATIN AMERICA				
Area	863	2.6	1,088	6.17
Prod.	903	2.1	1,246	8.28
Yield	1,050		1,150	

Table IV. World Production of Soybeans and Groundnuts (continued)

Region	Soybeans	% of Total	Groundnuts in Shell	% of Total
OCEANIA				
Area			27	.15
Prod.			32	.21
Yield			1,190	
MAINLAND CHINA				
Area	13,350F	39.78	1,900*	10.78
Prod.	10,670*	24.47	2,200*	14.63
Yield	800F		1,160*	
USSR				
Area	854	2.54	1	-
Prod.	528	1.21	1	-
Yield	620		630	
WORLD TOTAL				
Area	33,566		17,620	
Prod.	43,613		15,034	
Yield	1,300		850	

Area = 1000 Hectares
Production = 1000 Metric Tons
Yield = KG/Hectare

F = FAO estimate
* = Unofficial figure
(1) Peanuts
(2) Including India and Pakistan

1968 figures from 1969 Production Yearbook, Volume 23, Food and Agriculture Organization

Table V.
Important Legumes Grown in the Tropics and Subtropics *

Legume				
Latin name	Common name	Area of cultivation	Notes and comments	Reported yields Kg/ha
Phaseolus lunatus	Lima bean Butter bean	Tropical America, West Indies, tropical Africa, Madagascar, New Guinea, and north Australia.	Usually annual but may be perennial. Maturing period 4-6 months. Needs warm, humid climate.	400-1,500
Phaseolus aureus	Mung bean Golden gram Green gram	South and east Asia, particularly India, east Africa.	Annual. Maturing period 2-4 months. Moderately resistant to drought and high temperatures. The sprouted seed is a popular vegetable in China. In India the green pods are eaten and the dry grams are often pounded into flour.	300-600
Phaseolus mungo	Urd bean Black gram	India, Africa, and West Indies.	Annual. Maturing period 2-1/2 to 5 months. Rather susceptible to drought. Like Phaseolus aureus is highly valued in India. Eaten by Indian immigrants in Africa, the West Indies, etc.	200-700
Phaseolus vulgaris	Dry bean Kidney bean French bean Haricot bean	Grown throughout the world, but particularly in the Americas.	Annual. Maturing period 2-5 months. Susceptible to high temperatures, frost, and drought. Includes many varieties, varying in color and size.	400-2,500
Pisum sativum	Dry pea Garden pea English pea	Throughout the temperate zone. Grown in warm countries as a cold weather crop or at high altitudes.	Annual. Maturing period 3-5 months. Susceptible to high temperatures and drought. Eaten in fresh or dry form. A popular small garden product in temperate countries. Now also cultivated on a commercial scale and widely consumed in canned and frozen form.	500-1,500

Table V. Important Legumes Grown in the Tropics and Subtropics (continued)

Legume: Latin name	Legume: Common name	Area of cultivation	Notes and comments	Reported yields
Pisum arvense	Austrian winter pea Field pea	Similar to those of Pisum sativum but is grown much less extensively.	Annual. Maturing period 4-5 months. Moderately resistant to high temperatures, frost, and drought. Might perhaps be described as a poor but hardy relation of the garden pea. Often used for green manure.	400-1,200
Vicia faba	Broad bean Horse bean Bell bean	Temperate zone, particularly the Mediterranean region, highlands in Asia, Africa, and Central and South America.	Annual, sometimes biennial. Maturing period 3-7 months. Moderately resistant to high temperatures and drought. Includes many varieties.	500-2,300
Vigna sinensis	Cowpea Southern pea Blackeye pea	Tropical Asia and Africa, West Indies, southern Europe, and the Americas.	Annual. Maturing period 3-4 months. Resistant to high temperatures and drought, and to plant pests and diseases. Includes numerous varieties. The pods of the Vigna sp. are eaten as a vegetable in China and India.	300-1,000
Arachis hypogaea	Groundnut Peanut	Tropics and subtropics throughout most of the world.	Annual. Maturing period 4-5 months. Highly susceptible to frost and needs hot dry conditions for maturing. Primary use as source of oil. Seeds eaten directly in many places,in a variety of ways.	1,500-2,000
Cajanus cajan	Pigeon pea Arhar Red Gram	Grown in tropics and subtropics in Asia and Africa. Widely cultivated in India and Pakistan. Introduced into tropical America, Pacific Islands, and Australia.	Short-lived perennial but also grown as an annual. Maturing period 7 months. A dry crop, resistant to drought and high temperatures.	800-1,500

Table V. Important Legumes Grown in the Tropics and Subtropics (continued)

Legume: Latin name	Legume: Common name	Area of cultivation	Notes and comments	Reported yields
Cicer arietinum	Chick-pea Bengal gram	Grown in tropics and subtropics in Asia and Africa. Widely cultivated in India and Pakistan mainly as a cold weather crop. Also cultivated in Mediterranean countries and South America.	Annual. Maturing period 6 months. Moderately resistant to drought and high temperatures.	800-1,200
Dolichos lablab	Hyacinth bean	Dry tropical areas in Asia, Africa, West Indies, and Central America.	Annual. Maturing period 6-8 months. Also occurs as biennial and perennial. Moderately resistant to drought. Susceptible to disease in humid conditions. Includes garden "climbing" varieties grown to produce green beans.	500-1,500
Dolichos uniflorus	Horse gram	Tropics and subtropics in Asia and Africa.	Annual. Maturing period 7-8 months. Thrives on poor soils in dry tropical areas. Not in high regard as human food.	No information
Glycine max	Soybean	South and East Asia, particularly China and Japan (but not India) and U.S. In other parts of the world usually cultivated on a limited, often experimental scale.	Annual. Maturing period 5 months. Best suited to warm but not tropical climates. A valuable source of oil and livestock feed. Regularly eaten (in traditionally processed forms) in south and east Asia, but not in other regions.	1,000-2,000

Table V. Important Legumes Grown in the Tropics and Subtropics (continued)

Legume: Latin name	Legume: Common name	Area of cultivation	Notes and comments	Reported yields
Lathyrus sativus	Lathyrus pea Khesari dhal	Mainly India.	Annual. Maturing period 5-6 months. Hardy, drought resistant and grows on poor soils. Because of its resistance to drought has been an important "famine crop" in India, surviving, or cultivated, after cereals have failed. Eaten in large amounts in such circumstances it may produce the disease lathyrism.	No information
Lens esculenta	Lentil	Near East, north Africa, India, Burma, central and southern Europe.	Annual. Maturing period 5-6 months. Resistant to drought, and high temperatures. Includes orange-red and green varieties.	600-1,200
Parkia biglobosa (or P. filicoidea, P.africana)	African locust bean	West Africa.	A leguminous tree with pods maturing annually. The seeds are fermented and used as a condiment throughout west Africa. The pods contain a sweet yellow pulp used for making "sweets" or drinks.	No information

* "The Rockefeller Foundation Grain Legume Report Concerning the Lowland Tropical Regions of the Americas," by Dr. William J. Zaumeyer, April, 1968.

Table VI. Amino-Acid Content of Legumes

Legume	Isoleucine	Leucine	Lysine	Phenylalanine	Tryosine	S-cont.(total)	Methionine	Cystine	Threonine	Tryptophan	Valine	Protein score	Limiting amino acid (No. 1)	Limiting amino acid (No. 2)	References**
FAO Provisional Pattern	270	306	270	180	180	270	144	126	180	90	270	100			
Dry Seeds:															
Arachis hypogaea (peanut)	260	380	220	320	220	150	60	90	170	70	310	55	S.	Try.	1
Cajanus cajan (pigeon pea)	380	490	450	540	210	160	70	90	240	30	330	38	Try.	S.	1
Canavalia ensiformis (sword bean)	280	570	370	390	240	180	110	80	310	--	330	--	--	--	2
Cicer arietinum (chickpea)	360	460	430	300	210	170	80	90	220	50	310	57	Try.	S.	1
Dolichos biflorus (twin-flower Dolichos)	420	490	490	430	160	220	90	140	240	60	370	71	Try.	S.	1
Dolichos lablab (hyacinth bean)	260	490	430	270	220	130	60	70	230	--	290	--	--	--	2
Glycine max (soybean)	340	480	400	310	200	200	80	110	250	90	330	72	S.	Try.	1
Lens esculenta (lentil)	330	440	380	280	170	100	50	50	220	50	340	36	S.	Try.	1
Phaseolus acutifolius latifolius (tepary bean)	280	480	410	330	200	150	60	90	250	--	360	--	--	--	2
Phaseolus angularis (adjuki bean)	280	490	440	340	210	180	110	70	240	--	340	--	--	--	2

Table VI. Amino-Acid Content of Legumes (continued)

Legume	Isoleucine	Leucine	Lysine	Phenylalanine	Tryosine	S-cont.(total)	Methionine	Cystine	Threonine	Tryptophan	Valine	Protein score	Limiting amino acid (No. 1)	Limiting amino acid (No. 2)	References**
Phaseolus aureus (mung bean)	350	560	430	300	100	110	70	40	200	50	370	40	S.	Try.	1
Phaseolus lunatus (Lima bean)	360	520	420	370	160	190	100	90	300	60	390	66	--	--	2
Phaseolus mungo (urd bean)	270	490	460	410	210	140	90	60	230	--	370	--	--	--	2
Phaseolus vulgaris (dry bean)	360	540	460	350	240	120	60	60	270	60	380	46	S.	Try.	1
Pisum sativum (dry pea)	350	520	460	320	250	160	80	80	240	70	350	58	S.	Try.	1
Vicia faba (broad bean)	390	540	350	260	170	70	30	40	200	60	310	26	S.	Try.	1
Vigna sinensis (cowpea)	260	450	410	340	210	230	120	110	220	--	340	--	--	--	1
Immature Seeds:															
Phaseolus lunatus (Lima bean)	380	500	400	320	220	140	70	70	280	80	400	50	S.	Try.	1
Pisum sativum (dry pea)	290	390	300	240	150	120	50	70	230	50	260	44	S.	Try.	1
Vigna spp. (cowpea)	310	430	410	350	--	--	90	--	240	70	340	--	--	--	1

* mg/g N.

** 1 = Orr, M. L. and B. K. Watt. 1957. U.S.D.A. Home Economics Research Report No. 4.
2 = Cerighelli, R., F. Busson, J. Toury, and B. Bergeret. 1959. Annales. Nutrit. Alimentation, Vol. XIV, No. 2. 1960.

(Table from "The Rockefeller Foundation Grain Legume Report Concerning the Lowland Tropical Regions of the Americas," by Dr. William J. Zaumeyer, April, 1968.)

APPENDIX

The following pages contain certain more detailed information on each of the six major food legume crops that have been recommended for research in the international improvement program.

Brief descriptions are given of origin and distribution; growth habit and utilization; nutritive quality; yields (both those presently obtained by farmers and maximum yields reported by researchers); problems limiting production; and ongoing research programs, including information about institutions, personnel, and fields of activity.

The information is not considered to be complete. No attempt has been made to bring together all information available on each of these crops; this is obviously beyond the scope of this paper. More specific and detailed information is available in the literature; a selected bibliography is included at the end of this appendix.

It is recognized that the lists of institutions and workers concerned with improvement of the crops discussed in this report is far from complete. With the cooperation of many individuals and institutions, a more exhaustive listing is being compiled and will be available at a later date for those who may wish it. Exclusion of any particular institution or individual active in these crops is unintentional and in no way should be construed as a lack of appreciation for the importance of their work. The list should serve to indicate in a preliminary way the scope and depth of present activity.

BEANS
(*Phaseolus vulgaris*)

The Phaseolus genus covers a large number of species including *Phaseolus vulgaris* (common bean, dry bean, snapbean, kidney bean, haricot bean), *P. aureus* (mung bean), *P. mungo* (urd bean), *P. lunatus* (lima bean), *P. calcaratus* (rice bean), and several others of minor importance. Of these, *P. vulgaris* is by far the most important in both worldwide acreage and geographic distribution and consumption.

Origin and distribution

The common bean is a native of Central America, whence it spread to both North and South America. It was unknown in Europe until after the discovery of America.

It is grown on all continents but cultivation is mostly limited to the medium to higher elevations because of susceptibility to diseases and insects in the humid tropics. Major areas of production are the north-central and northwestern states of the United States, Central and South America, Europe, and countries in the Near and Middle East. It is the principal legume and the main source of protein in the human diet in most countries of Central and South America. Total world area is about 21 million hectares for a total production of 10 million tons. This represents about 18 percent of world acreage and slightly over 10 percent of world production of food legumes, including soybeans and peanuts.

Growth habit and utilization

Phaseolus vulgaris beans grow as annual herbaceous plants seldom taller than 24 inches, although climbing types normally grow higher. They mature in about three to six months. Usually they are consumed as cooked mature seeds, although the green pods are also eaten as a vegetable. Seed colors vary - the beans may be white, black, red, grey, or mottled. There are very specific consumer preferences for color in different parts of the world.

Nutritive quality

Phaseolus beans contain about 22 percent protein. They are high in lysine (7.4 percent of P) and threonine (4.3 percent of P), but low in sulphur amino acids - methionine, cystine, and also tryptophan. They are reported as high in antimetabolites, the hemagglutinins, and trypsin inhibitors, as well as flatus-producing factors.

Yields

Reported average yields range from as low as 300 to 500 kg/hectare in Asia and Africa to 1,300 to 1,500 kg/hectare in North America. Much higher yields, as high as 4,000 kg/hectare, have been reported. Low yields in the developing countries are due mainly to a combination of factors, including the use of varieties low in inherent yield potential and susceptible to a wide range of diseases (including fungal, bacterial, and viral diseases) and insects (from seed corn maggots, *Hyleuria cilicrura*, which attack the emerging seedling, to leaf-chewing and sucking insects, to pod borers such as *Heliothis zea*), and lack of good crop management practices, including low seeding rates, poor soil fertility, unfavorable moisture conditions, etc.

Potential yields

There is little sound information on the yield potential of this crop. Efficient farmers in the United States, using improved varieties, good quality seed, and all other practices of modern mechanized farming, have realized yields of 3,000 to 4,000 kg/hectare. Similar yields have been reported from experimental plots in Asia using local cultivars and good farming practices of irrigation, fertilizer, and pest control. Whether this yield ceiling can be exceeded can only be determined by in-depth research on all aspects of the plant and its culture.

Problems of production

Varieties: Considerable varietal development research has been done in the United States and Europe, as a result of which improved varieties with adaptation to specific bean-growing areas are available.

However, this is not the case in the developing countries, where farmers usually use seed from their own previous harvests. Research programs in various countries have developed "improved" varieties, but these are mostly products of a narrow genetic base and therefore are not outstandingly superior; furthermore, they seldom reach farmers' fields for lack of sound extension programs and seed distribution systems.

Diseases: Phaseolus beans, like most other legumes, are susceptible to a wide range of insects and diseases, especially in the hot humid tropics. The following diseases are of importance in limiting bean production. Those caused by bacteria and fungi are more important in the lowland humid tropics and subtropics, while viruses are generally more severe in the drier climates.

Fungal and bacterial diseases:

Round spot	*Chaetoseptoria wellmanii*
Anthracnose	*Colletotrichum lindemuthianum*
Powdery mildew	*Erysiphe polygoni*
Dry root rot	*Fusarium solani f. phaseoli*
Angular leaf spot	*Isariopsis griseola*
Downy mildew	*Phytophthora phaseoli*
Web blight	*Pellicularia filamentosa*
Rhizoctonia root rot	*Rhizoctonia solani*
White mold	*Sclerotinia sclerotiorum*
Southern blight	*Sclerotium rolfsii*
Bean rust	*Uromyces phaseoli* var. *typica*
Common blight	*Xanthomonas phaseoli*
Alternaria leaf spot	*Alternaria phaseoli*
Ascochyta leaf spots	*Ascochyta boltshauseri* and *A. phaseolorum*
Cercospora leaf spot	*Cercospora cruenta*
Pythium root rots	*Pythium aphanidermatum* and *P. debaryanum*
Ramularia leaf spot	*Ramularia phaseolina*

Virus diseases:

Bean common mosaic (seed transmitted)
Bean yellow mosaic
Cucumber mosaic
Curly top
Pea leaf roll

Insects: Weevils and bruchids cause direct damage to seed in storage; seed corn maggots, to emerging seedlings; and various sap-sucking or leaf-chewing insects, to growing plants. A complex of pod borers cause varying degrees of damage to developing pods and seeds. Aphids, white flies, and leafhoppers are the vectors of virus diseases.

Losses due to insects that attack the standing crop in the field have been reported to be as high as 100 percent for seed corn maggot, as high as 60 percent for pod weevils. Losses to seed in storage may be as high as 40 to 50 percent due to bruchids and other seed-destroying insects.

The following insects are of major economic importance in various bean-growing areas of the world:

Whitefly	_Bemisia tabaci_
Pod weevil	_Apion_ spp.
Leafhopper	_Empoasea_ spp.
Spider mite	_Tetranychus telarius_
2-spotted mite	_Tetranychus bimaculatus_
Aphid	_Acyrthosyphon sesbanial_
Cut and army worms	various types
Leaf chewing insects	various types
Banded cucumber beetle	_Diabrotica balteata_
Mexican bean beetle	_Epilachna varivastis_
Benchids	_Callosobrucbus maculatus_

Production practices: Bean production, like that of all food legumes, is low in many areas because of a lack of information, knowledge, and solutions to problems. Among the most serious factors which limit production are: 1) insufficient plant populations due to low seeding rates, poor quality seed, unsatisfactory planting methods and losses from insects and seedling diseases; 2) lack of information on fertilizer response, including inoculations with rhizobial cultures for nitrogen fixation; 3) losses from insects and diseases for which effective controls are not yet available; and 4) shortage of moisture during critical periods in the growing season.

Present research

There is probably more research being done in the world on Phaseolus beans than on any other food legume crop except soybean. Much of it, however, is on rather specific problems (often diseases and insects) of importance to relatively small areas. There has been a lack of coordination among workers, and the research has not built up a coordinated body of knowledge about the crop. The following is a partial list of institutions and workers concerned with bean improvement:

AFRICA

Uganda

Makerere University
Kampala

C. L. Leakey	Breeding; diseases

ASIA

Iran

Same program and staff as listed under Cowpeas

Japan

Hokkaido University
Sapporo

K. Gotoh	Breeding for earliness, large seed size, yield
J. Ishizuka	Cold damage to beans

Aomori Prefectural Agricultural Experiment Station
Aomori

R. Kawashima	Breeding

Turkey

Seed and Plant Improvement Station
Eskisehir

Nihot Canitez	Selection from germplasm

Samsun Crop Research Station
Samsun

Hüsnu Çinar	Agronomy; cultural practices

Plant Introduction Station
Ismir (FAO)

Hyla Sencer (Swedish FAO technician)
Ebbe Kjellqurist (Swedish FAO technician)

Storage of germplasm collections of cereals and pulses

AUSTRALIA

Queensland Department of Primary Industries
Brisbane

G. M. Behneken   Inheritance of disease resistance

EUROPE

England

Department of Agricultural Sciences and Applied Biology
University of Cambridge
Cambridge

Alice M. Evans

Work with interdisciplinary team to breed high-yielding, disease-resistant varieties

Unilever Research Laboratories
Sharnbrook
Bedford

Peter Kyle
Alan Wharton   Pathology

Interdisciplinary team approach to development of improved varieties through breeding; studies of halo blight and anthracnose

France

Station Centrale d'Amélioration des Plantes
Versailles (Seine-et-Oise)

H. E. Bannerot

Breeding for resistance to diseases and insects; inheritance of disease resistance

Germany

Institut für Pflanzen Pathologie
Gottingen

K. Rudolph

Pathology; bacterial diseases; nature of resistance

Netherlands

Instituut voor Plantenziektenkundig Onderzoek
Wageningen

I. N. Hubbeling

Pathology; breeding; breeding for diseases resistance; genetics

Spain

Ministerio de Agricultura
Instituto Nacional de Investigaciones Agronómicas
Centro de Cerealicultura
Madrid

Amelia Alonso Pathology

Instituto Nacional de Investigaciones Agronómicas
Centro de Cerealicultura
Avenida Puerta de Hierro

Rafael Ruiz-Fornells Breeding for disease resistance

Instituto Nacional de Investigaciones Agronómicas
Madrid

José Puerto Romero

Breeding for resistance to diseases and insects

LATIN AMERICA

Brazil

Estacão Experimental de Uberaba
Uberaba, Minas Gerais

Ricardo Jose Guazzelli Agronomist

Instituto de Pesquisas Agronômicas
Recife, Pernambuco

Mario Coelho de Andra de Lima Agronomist

(Brazil)

Instituto Agronômico
Secão de Leguminosas
Campinas, São Paulo

Shiro Miyasaka	Pathologist, Breeder, Coordinator
A. S. Costa	Virologist
Antonio Sidney Pompeu	Breeder
Hipolito A. A. Mascarenhas	Agronomist

Instituto Biologico
Campinas, São Paulo

Eduardo Issa	Pathologist

Catedratico - UREMG
Viçosa, Minas Gerais

Clibas Vieria	Breeder and Pathologist

Ministerio de Agricultura (IPEAS)
Pelotas, Rio Grande do Sul

Joaquim Geraldo da Costa	Breeder
Ivanoska Rodriques Diaz Filha	Pathologist

Chile

Facultad de Agronomía
Universidad Católica
Santiago

Alonso Bravo M.	Pathologist

Instituto de Investigaciones Agropecuarias
Santiago

Milan Caglevic	Pathologist
Mario Alvarez	Virologist
Abraham Ziver	Breeder and Pathologist

Colombia

Bean Improvement Program
Instituto Nacional de Investigaciones Agropecuarias
Palmira

Luis H. Camacho — Breeder
Interdisciplinary team of other breeders, pathologists, entomologists, and agronomists

Development of disease-resistant types

Costa Rica

Instituto Interamericano de Ciencias Agrícolas de la OEA
Centro de Enseñanza e Investigación
Turrialba

A. Pinchinat — Breeder

El Salvador

Centro Nacional de Agronomía
Ministerio de Agricultura y Ganadería
Santa Tecla

Bernardo Patino — Pathologist

Agricultural Experiment Station
Ministerio de Agricultura y Ganadería
San Andrés

Cristalos Rodolfo Pinada — Agronomist

Guatemala

Dirección Investigaciones
Ministerio de Agricultura
Guatemala City

Eugenio Schieber — Pathologist

Screening and breeding for resistance to major diseases

Honduras

Escuela Agrícola Panamericana
Zamorano

George Freitag	Botanist

Maintains large collection of bean germplasm including wild types; has made many wide crosses; makes segregates available to breeders

Mexico

Secretaria de Agricultura y Ganadería
Instituto Nacional de Investigaciones Agrícolas
Mexico, D.F.

Alfonso Crispin M.	Pathologist

Breeding for higher-yielding varieties with disease and insect resistance

Peru

Estación Experimental Agrícola la Molina
Lima

Santiago Bocanegra	Breeder and Coordinator
Oswaldo Voysest V.	Breeder
Segundo L. Dongo	Agronomist

Venezuela

Centro de Investigaciones
Maracay

Alfredo Barrios	Breeder
Simon Ortega	Breeder

UNITED STATES

California

Western Utilization Research Division, USDA
Albany

H. K. Burr

Composition and properties of dry beans, peas, and lentils

Colorado

Department of Botany and Plant Pathology
Colorado State University
Fort Collins

N. Oshima   Pathology

Department of Agronomy
Colorado State University
Fort Collins

D. R. Wood

Breeding for disease resistance and improved protein; study of the nature and inheritance of Fusarium root rot resistance in beans; improvement of the value of protein in dry beans

District of Columbia

Commodity Facilities Branch
Economic Research Service
Washington, D.C.

Idaho

Branch Experiment Station
Kimberly

Marshall LeBaron

Breeding for disease resistance; crop management

Northwest Branch
SWC Research Division, ARS
Snake River Conservation Research Center
Twin Falls

G. E. Leggett

Soil science; nutrient availability and balance for maximum crop production in the Snake River Plains

Michigan

Department of Crop and Soil Science
Michigan State University
East Lansing

M. Wayne Adams

Breeding for disease resistance; bean breeding and genetics

Plant Pathology Department
Crops Research Division, ARS, USDA
Michigan State University
East Lansing

A. W. Saettler

Plant pathology, disease control, and varietal improvement of dry beans in the North Central States

Nebraska

Scotts Bluff Agricultural Experiment Station
Scotts Bluff Station
Mitchell

F. N. Anderson

Varietal testing; dry bean variety test

Department of Horticulture and Forestry
University of Nebraska
Lincoln

Dermot P. Coyne

Breeding and genetics; breeding for disease resistance; inheritance

Entomology Department
University of Nebraska
Lincoln

A. F. Hagen Entomology

(Nebraska)

Plant Pathology Department
University of Nebraska
Lincoln

M. L. Schuster

Pathology, biology, and control of nematode and bacterial diseases of crops

New Jersey

Pioneer Research
Campbell Institute for Agricultural Research
Riverton

J. F. Kelly — Protein studies

New York

Department of Food Science and Technology
New York Agricultural Experiment Station
Geneva

R. L. Hackler

Human nutrition; nutritional value of processed beans

Department of Vegetable Crops
Cornell University
Ithaca

J. L. Ozbun

Physiology, high yield on basis of variation in photosynthetic efficiency

Department of Plant Breeding
Cornell University
Ithaca

J. N. Rutger

Breeding; studies of protein and oil content and improvement of protein quality in beans

(New York)

Department of Vegetable Crops
Cornell University
Ithaca

R. F. Sandsted — Crop Management

Department of Plant Breeding
Cornell University
Ithaca

D. H. Wallace

Breeding for disease resistance; genetics

Department of Plant Pathology
Cornell University
Ithaca

R. E. Wilkinson

Pathology, root rot, and other diseases of beans

Oregon

Vegetables and Ornamentals Branch
CR, ARS, USDA
Oregon State University
Corvallis

R. O. Hampton

Pathology; identification and characteristics of pea and bean viruses

Washington

Vegetables and Ornamentals Branch
CR, ARS, USDA
Irrigation Agriculture Research and Extension Center
Prosser

D. W. Burke	Breeding and pathology
M. J. Silbernagel	Breeding and pathology

(Washington)

Regional Plant Introduction Station
Washington State University
Pullman

S. M. Dietz — Plant introduction

Department of Agricultural Chemistry
Washington State University
Pullman

J. M. Lawrence — Agricultural chemistry

Wyoming

Department of Plant Science
University of Wyoming
Laramie

C. W. McAnelly

Pathology, nature and inheritance of Fusarium root rot resistance in beans

G. H. Bridgmon — Varietal testing

COWPEAS
(Vigna sinensis)

Origin and distribution

Cowpeas most likely originated in Africa, but they have spread throughout the world. There are a number of related species in the genus Vigna, and the classification of the Old World types in relation to some of the New World food legumes presently in the Phaseolus genus is in a state of uncertainty. Tourneur and Hepper (1958) have classified *Phaseolus aureus* (mung bean), *P. mungo* (urd bean) and *P. radiatus* as *Vigna mungo* because they resemble the Old World species of the Vigna genus more closely than the New World species of Phaseolus. There are two other species of Vigna: *V. unguiculata* (wild cowpea) and *V. sinensis* (cowpea). The *Vigna sinensis* is by far the most common, and most widely grown of the species used for human consumption.

Cowpeas are grown throughout the world wherever suitable climates occur. They are cultivated in Europe, Africa, Asia, Australia, and both North and South America.

Total world acreage is around 2.8 million hectares of which almost 2.6 million are in Africa. Of the total production of 1.08 million tons, over one million tons is produced in Africa. Average worldwide yield is about 385 kg/hectare.

Growth habit and utilization

Cowpeas are a herbaceous annual crop. There exists a large variety of forms from small erect plants, maturing in 60 to 70 days, to large spreading types with a prostrate habit of several meters spread and requiring six to eight months to mature. Pod shape and size, and seed shape, size, and color also vary widely. The great variability occurring in characteristics such as plant habit, seed and pod characteristics, photoperiodic responses and other traits has caused the confusion in the botanical classification and the designation of different species and forms.

They are generally sown at the beginning of the rainy season, although they may also be found as an irrigated crop or may be sown toward the end of the rainy season and grown on residual moisture.

Cowpeas are the most important food legume in Africa after peanuts. They are eaten as a vegetable in the green pod form, as dried beans, and as sprouted seedlings. The tender green leaves are also picked and cooked as a green vegetable. Their most important use is in the form of dried beans for human food, with the crop residue used for stock feed. In other countries, they may be grown as a green manure crop, for erosion control, or as a fodder, as well as for canning and direct human consumption.

Seed colors vary from white to cream, with varying degrees of mottling of the seed coat and varying intensity or total absence of a black ring around the hilum (hence the designation black-eye pea). Different areas have different preferences for specific colors.

Nutritive quality

Cowpeas have excellent nutritive characteristics, with an average total protein of 23 percent. Along with pigeon peas, they rate highest in methionine (1.9 percent of protein), the amino acid which is generally lacking in food legumes.

There are no reports of antimetabolic factors or toxic components in cowpeas.

Yields

Worldwide cowpea yields average about 385 kg/hectare. Africa averages 370 kg/hectare; the rest of the world, around 766 kg/hectare. This is accounted for by the fact that the "rest of the world" includes developed countries where more advanced farming methods and improved varieties produce better yields. Yields of 2,000 kg/hectare have been reported from experimental plantings in yield trials and agronomic experiments of the USDA/AID Regional Pulse Improvement Project in Iran.

Low yields are mostly due to use of varieties having a low yield potential and to lack of good crop management practices, including all factors from sowing through harvest.

Potential yield

Yields reported from developed countries and those from research trials in developing countries (as cited above) indicate only the minimum potential of cowpeas.

Although research has been conducted in the United States, leading to a number of improved varieties and recommended cultural practices, there has been very little work done, outside of a few isolated, sporadic projects, to improve production in Africa, where the crop is of major importance. At present, most of the cowpea crops are sown, cultivated, and harvested by hand, especially in Africa.

As is the case with all other food legumes, the true potential of cowpeas has not been determined. The great variability encountered in the germplasm in a wide range of characters opens the way for a well coordinated, multidisciplinary research program which should lead to breakthroughs for this crop.

Problems of production

Varieties: Improved varieties have been developed in the United States, where the crop is decreasing in importance and will perhaps continue to decline because of competition from other more productive and profitable crops, such as soybeans. A few other scattered varietal improvement programs have been conducted in South Africa, Nigeria, a few other African countries, India, Iran, and Australia.

Because of the limited scope of the programs and the narrow genetic base of the plant material worked with in developing countries, few improved, high-yielding varieties have been developed in these programs.

Diseases: Cowpeas are susceptible to a large number of serious diseases. Reports cite rust (*Uromyces phaseoli*), leaf and pod spot (*Ascochyta phaseolorum*), bacterial canker (*Xanthomonas vignicola*), Fusarium wilt (*F. oxysporum*), powdery mildew (*Erysiphe polygoni*), stem rot (*Phytophothora vignae*) as being principal diseases in Africa, the United States, and Australia.

Virus diseases can cause very serious yield reductions. Yellow mosaic virus is particularly severe in India and Iran but occurs elsewhere also. Seed-borne virus diseases including southern bean mosaic and bean yellow mosaic are the most serious diseases of cowpeas in the southern United States.

Insects: A large number of insects attack cowpeas from seedling stage to after harvest in storage. The bean fly (*Madurasia obscurella*), thrips, leafhoppers (*Empoasca fabae*), flea beetles (*Madurasia obscurella*), curculio weevils (*Chalcodermus aeneus*), bruchids (*Callosobruchus chinensis*, *C. maculatus*, *C. analis*) are among the more serious insect pests.

Many of these can be controlled with presently available insecticides. However, insecticides can be of considerable danger in the hands of uneducated, often illiterate peasant farmers. Also, even the insecticides that are simplest to use usually require more knowledge and equipment than is available to the farmer. They are often not available when and where they are needed. Therefore, development of resistant varieties appears to be the best long-term method of control.

Nematodes: The same holds true for nematodes. J. P. F. Sellschop, in a report from South Africa (1962) states, "Probably no other organism is so widely distributed in cowpea-producing areas and as destructive as certain species of nematodes (Meloidogyne spp.)." Although no resistance was found in many years of searching, it is possible that the range of germplasm screened has not been wide enough. Also, the possibility of finding resistance in wild species of Vigna must not be overlooked.

Production practices: Cowpeas, like other food legume crops in developing countries, receive little more than minimum care. They are usually planted in mixtures with one or more other companion crops. Often seeding rates are too low, resulting in a poor stand. No fertilizer or irrigation water is given, even though research has shown a definite benefit from applications of phosphate fertilizers and from irrigation in areas where rainfall is low, particularly during the flowering and fruiting periods. As mentioned before, no pesticides are applied, and damage due to pests and diseases goes uncontrolled. Shattering of seeds from pods in the field prior to harvest can cause serious losses, and development and use of shatter-resistant varieties appears to be the only method of control.

High yields of cowpeas have been obtained with careful management of the crop, but a great deal of research is required to put the possibility of consistently good yield within the grasp of the peasant farmer, to whom this crop is most important.

Present research

Work on cowpea improvement in the United States dates back to the turn of the century; it has been done in Florida, Alabama, Mississippi, Georgia, South Carolina, Arkansas, Virginia, Louisiana, Texas, Oklahoma, and California. Some work has also been carried on in Nigeria, South Africa, and Uganda. In Venezuela and Argentina, cowpeas were found to be less susceptible to disease than the more commonly grown Phaseolus beans. There has also been some work in Colombia. Research on cowpeas has also been reported from India, Iran, and Australia.

The most effective research, from the standpoints both of finding answers to problems and of applying the research findings on the farm, has been done in the United States.

More recently research programs on cowpeas have been started in Iran and India as part of the USDA/AID Regional Pulse Improvement Projects in collaboration with national institutions in these two countries, with focus on varietal improvement, disease and insect investigations, and work on crop and soil management.

Makerere University, Kampala, Uganda, is giving emphasis to food legumes, among them cowpeas, with financial support from the Overseas Development Ministry of the United Kingdom, The Rockefeller Foundation, Norwegian AID Fund, and U.S. AID.

The following is a partial list of cowpea workers in various countries:

AFRICA

<u>Nigeria</u>

Institute of Agricultural Research
Ahmadu Bello University
Zaria

W. M. Steele	Breeder

Federal Department of Agricultural Research
Moor Plantation, Ibadan

U. U. Ebong	Breeder
O. Ojeaga Ojehomon	Plant Pathologist

Collecting of germplasm; breeding for yield, seed types, photoperiodic insensitivity, disease resistance, uniform ripening

University of Ife
Ile-Ife

LeRoy N. Barker
F. A. Bliss

Inheritance studies; screening for resistance to yellow mosaic and cowpea mottle viruses, stem anthracnose (<u>Colletotrichum</u> sp.), web blight (<u>Rhizoctonia</u> sp.), basal stem rot, and leaf diseases

Senegal

Centre National de Recherches Agronomiques
Bambey

D. Sene	Breeder

Breeding and varietal trials for yield, earliness, photo-insensitivity, upright plant type

South Africa

College of Agriculture
Research Institute
Potchefstroom

J. D. F. Sellschop	Agronomist

Uganda

Makerere University
Kampala

C. L. A. Leakey	Breeder, Pathologist
P. N. Mehta	Breeder

ASIA

India

All-India Coordinated Pulse Project
Indian Agricultural Research Institute
New Delhi

(See Pigeon Peas)

Uttar Pradesh Agricultural University
Pantnagar

(See Pigeon Peas)

Uttar Pradesh State Department of Agriculture
Kanpur

S. S. Saxena	Breeder

Punjab Agricultural University
Ludhiana

K. B. Singh	Breeder

Iran - In cooperation with USDA/AID Regional Pulse Improvement Project:

Karaj Agricultural College
Karaj

M. C. Amirshahi	Breeder
H. Sarazdaghi	Agronomist
A. Solar-i-dini	Agronomist
F. Eskanderi	Pathologist
M. Esmaeli	Entomologist
M. Omidvar	Nematologist
G. M. Horner	Agronomist, USDA
K. H. Evans	Breeder, USDA
W. J. Kaiser	Pathologist, USDA

Breeding; crop management; diseases; insects; nematodes

Pahlavi University Agricultural College
Shiraz

M. Niknejad	Breeder
K. Ezadpaheh	Pathologist
S. Sherifi	Entomologist
B. Bahrani	Agronomist

Breeding; crop management; diseases; pest control

Ministry of Agriculture
Seed and Plant Institute
Tehran (and stations throughout Iran)

P. Parvaneh	Varietal testing

LATIN AMERICA

Colombia

Instituto Nacional de Investigaciones Agropecuarias
Palmira

Luis H. Camacho	Head of bean improvement program

Development of adapted cowpea varieties

UNITED STATES

Alabama

Auburn University
Auburn

O. L. Chambliss

Breeding southern peas for yield; nature of resistance to cowpea curculio; mechanical harvesting; disease resistance; insects; nematodes

Arkansas

Department of Horticulture and Forestry
University of Arkansas
Fayetteville

John L. Bowers — Breeding and selecting southern peas

Florida

Department of Vegetable Crops
University of Florida
Gainesville

Albert P. Lorz

Breeding activities involving lima and butter beans, bush snap beans, bean species hybrids, leaf crops, southern peas

Georgia

Crops Research Division, ARS
U.S. Department of Agriculture
Georgia Coastal Plain Experiment Station
Tifton

J. Danny Gay

Plant pathology; diseases of southern peas; breeding for disease resistance

Crops Research Division, ARS, USDA
State Agricultural Experiment Station
Experiment

W. R. Langford — Plant introduction
G. Sowell — Pathological evaluation of introductions

(Georgia)

Department of Entomology
Georgia Coastal Plain Experiment Station
Tifton

R. B. Chalfant — Insect control

Division of Horticulture
University of Georgia
Athens

C. H. Hendershott — Division Chairman

Plant physiology; influence of light, temperature, and growth regulators on growth and development

Georgia Agricultural Experiment Station
Griffin

Blake B. Brantley

Breeding for disease resistance, yield, and quality in southern peas

Mississippi

Department of Plant Pathology and Weed Sciences
Mississippi State University
State College

Woodrow W. Hare

Plant pathology and breeding; cowpea diseases; resistant factors

South Carolina

Department of Horticulture
Clemson University
Clemson

W. L. Ogle

Breeding southern peas with resistance to mosaic, nematodes, powdery mildew, and Fusarium wilt

Virginia

Virginia Truck Experiment Station
Norfolk

William H. Brittingham — Varietal testing

PIGEON PEAS
(Cajanus cajan)

Origin and distribution

Pigeon peas are probably a native crop of South and Southeast Asia. From there, they were most likely introduced into Africa and tropical America.

Pigeon peas are the second most important food legume crop in India. The crop is also widely grown in East Africa and in Central and South America.

Total world acreage is nearly three million hectares, which produce some 1.8 million tons of pigeon peas. India is the leading producer with 2.5 million hectares and 1.7 million tons of production.

Growth habit and utilization

The pigeon pea is a perennial, erect, coarse plant, grown mostly as an annual. It is deep rooted, grows as tall as eight to ten feet in height, and once established is quite drought tolerant. Maturity range is from as early as 120-150 days to as late as 300-360 days depending on cultivar or type and location where grown. The pigeon pea shows considerable photoperiodic response. In northern India, certain types, planted any time between March and July, will flower in September and will mature in November or early December, regardless of planting dates. Similar effects have been observed in Puerto Rico. This is important in development of new varieties, particularly early-maturing, shorter-growing types.

The pigeon pea is one of the few food legume crops that is partially cross-pollinated. The level of natural outcrossing ranges from 5 to 25 percent depending primarily on the presence of suitable insect pollinators. This natural outcrossing provides an opportunity for population improvement in varietal development programs, but it necessitates extra precautionary measures for maintenance of purity in genetic stocks and varietal seed increase.

In India, the crop is generally sown at the beginning of the rainy season in July in mixed planting with sorghum or millets. When the sorghum or millets are harvested in November, the pigeon peas are left as a single crop until harvested in March or April. The crop is used almost exclusively as a dry pulse for preparation of dal. In Africa and Latin America, the green pods are also consumed as a fresh vegetable or used for canning. The late-maturing, tall-growing types used in India produce thick woody growth which is used widely for fuel.

Seeds are generally round, smooth skinned and small (about 5,000 per pound). Seed colors vary from white through various shades of brown and red to black.

Nutritive quality

The amino-acid spectrum of pigeon peas is similar to that of soybeans, but pigeon peas have the advantage that they require no special processing for human consumption.

The average total protein is 20 to 23 percent. They are high in lysine (7 percent) and among the food legumes rank among the better ones in methionine (1.4 percent).

They are reported to be low in antimetabolites. No other toxic factors have been reported.

Yields

Pigeon peas are among the better yielding food legume crops, even though the world average of approximately 600 kg/hectare is still a low yield. If taken in relation to the length of time required to produce the crop (or in other words calculating yield per day), pigeon pea as grown in most areas is a very inefficient crop. Traditional cultivars in India, where over 90 percent of the world's pigeon peas are grown, are long-duration types (300 days from planting to harvest), and average yields are around 700 kg/hectare.

There are few other yield reports. The low yields of pigeon peas are mainly due to varietal characteristics and lack of good management.

Potential yield

Yields recorded from experimental plantings give some indication of the potential of this crop. In India, the USDA/AID Regional Pulse Improvement Project and Uttar Pradesh Agricultural University have reported yields in excess of 5,000 kg/hectare using a local variety, which was planted with a population of 50,000 plants per hectare and given fertilizer, plant protection, and irrigation. This crop was obtained in 150 days from planting to harvest and was followed by a wheat crop.

Workers in Puerto Rico have reported yields over 4,000 kg/hectare.

No really concentrated effort has been made anywhere to study all aspects of this crop and exploit its true production potential. If yields of 5,000 kg/hectare can be obtained with present varieties and knowledge of management, it appears not beyond the realm of expectation that this yield can be substantially improved.

That the yield of protein can be improved is clear from data reported on the variability of protein content: in 1,800 germplasm samples analyzed in India, total protein ranged from 18 to 32 percent.

Problems of production

Varieties: Present varieties are mostly inferior. No breeding programs have been conducted until very recently, except for a few programs of plant selection from existing local types. With the exception of lines developed in Puerto Rico, there are no varieties available today which have been developed in modern, comprehensive breeding programs. Pigeon peas in India are grown almost entirely from farmer-grown seed of unimproved varieties, which consists of local types without ever any conscious effort toward improvement.

Diseases: Pigeon peas are relatively disease free, although there are diseases that take a certain toll, such as wilt (*Fusarium udum*), stem blight (*Phytophthora drechsleri*), root rots (various organisms), and sterility mosaic virus.

There are no diseases as consistently and devastatingly harmful to pigeon peas as, for instance, wilt and blight to chick-peas, but diseases can and do reduce yields.

Insects: Pigeon peas are susceptible to a range of foliage-damaging insects. Nematodes have also been known to ruin stands of pigeon peas. Developing pods on the plants are subject to attack by a complex of various pod-boring insects, including *Ancylostomia* and *Heliothis* species, which destroy the developing seeds inside and cause considerable losses.

Stored pigeon pea seed is extremely susceptible to attack by species of the Bruchidae family, including *Callosobruchus maculatus*, *C. chinensis* and *C. analis*, which lay eggs on the seeds. The emerging larvae bore into the seed for feeding and pupation. The insects continue to reproduce and can render seed in storage completely unfit for consumption or any other use.

Production practices

Pigeon peas are generally sown in widely spaced rows between rows of another crop, usually sorghums or millets. The plant makes little growth until the companion crop is harvested; at that time the pigeon pea crop is left, with the plants too far apart to give high yield per hectare. No further attention is paid to the crop until harvest five months later. A yield of 600 kg/hectare is the best that can be expected under those circumstances.

Present research

Very little work has been done on the improvement of pigeon peas. Even in India, where more than 90 percent of the world's pigeon peas are grown, research efforts have been limited and sporadic. Only in very recent years has this crop begun to attract some attention.

The following is a list of some of the institutions and workers concerned with pigeon pea improvement.

AFRICA

Uganda

Makerere University
Kampala

K. O. Rachie	Breeder, Agronomist
I. Witham	Biochemist

Began breeding program on pigeon peas in 1969 with screening of Indian germplasm collection

ASIA

India

All-India Coordinated Pulse Project
ICAR, Ministry of Food and Agriculture, assisted by USDA/AID
Regional Pulse Improvement Project
(Main location at Indian Agricultural Research Institute, New Delhi)

S. Ramanujain	Coordinator
L. M. Jeswani	Breeder
S. L. Choudhury	Agronomist
J. S. Grewal	Pathologist
H. K. Saxena	Entomologist

Multidisciplinary approach to crop improvement on several of the food legume crops. Collection of extensive germplasm materials

Madhya Pradesh Agricultural University
Jabalpur

Laxman Singh — Breeder
Staff members in other departments

Improvement of pigeon peas, lentils, Lathyrus, mung beans

Uttar Pradesh Agricultural University
Pantnagar

M. D. Saxena	Agronomist
B. P. Pandya	Breeder
Y. Nene	Pathologist
J. P. Singh	Agronomist - soils
J. S. Naresh	Entomologist

Screening of germplasm; studies of production practices; work on major virus diseases of several food legumes including pigeon peas, chick-peas, lentils, cowpeas, mung beans, urd beans, and peas; emphasis on pigeon peas of early-maturing, semi-dwarf varieties

Uttar Pradesh State Department of Agriculture
Kanpur

S. S. Saxena — Breeder

LATIN AMERICA

Puerto Rico

University of Puerto Rico
Mayaguez (and Isabella substation)

Raul Abrams	Breeder

Development of improved varieties suitable for canning as well as for dry consumption; agronomic research

WEST INDIES

University of the West Indies
Mona, Jamaica

Vernon Royce	Breeder
R. E. Pierre	Pathologist
K. Thompson	Horticulturist

St. Augustine, Trinidad

E. F. Iton	Pathologist
S. Parasram	Entomologist

Development of improved varieties with dwarf and determinate growth and early maturity; research in agronomic, pest, and disease problems

CHICK-PEAS
(Cicer arietinum)

Origin and distribution

Considered to have originated in West Asia and around the Mediterranean, this species is grown widely in Asia as far east as Burma. It is of less importance further east. It is also grown in southern Europe, Africa, and Latin America. Total world acreage is around 10.8 million hectares, producing some seven million tons of chick-pea seed. India is the largest single producer (75 percent), followed by Pakistan (10 percent).

Chick-pea is grown mostly in areas with tropical or subtropical climates, during seasons of low rainfall. In India and Pakistan, it is grown during the winter (cool) season on residual moisture, and is sometimes given one or two irrigations.

The green pods are used as a vegetable; the seed is cooked as a vegetable or ground into flour. The vegetative parts of the plants are used for hay and fodder.

Growth habit and utilization

Chick-pea is a small-growing (18- to 24-inch) shrubby annual that matures in 120 to 150 days. Seed colors include light cream, brown, green, and black. The light cream-colored, large-seeded types (1,500-2,000 seeds per pound) are preferred in most areas outside India and Pakistan, where they are used as a vegetable. Utilization of the black, small-seeded types (4,000 to 5,000 seeds per pound) is limited almost exclusively to countries in the Middle East (Turkey, Iran) where they are dehulled and split before being used as a vegetable. The brown and green, medium-sized types (2,500 to 4,000 seeds per pound) are grown mostly in India and Pakistan and are used in many ways; they are eaten roasted, cooked as vegetable, or ground into flour.

Nutritive quality

Average total protein is 20 to 22 percent. Chick-pea is high in lysine but low in sulfur amino acids, particularly methionine, cystine, and also tryptophan. A trypsin inhibiting factor has been isolated from chick-peas.

Yields

Reported yields vary from about 300 to 400 kg/hectare to 2,000 kg/hectare or more. Lowest yields are obtained in India and Pakistan; highest yields, in southern Europe and Mexico and other Latin American countries.

Low yields in developing countries are due to lack of information on how to grow the crop and to the use of varieties that have low inherent yield potential and high susceptibility to diseases (blight or wilt usually cause from 5 to 50 percent loss every year in India and Pakistan) and insects; the crops are grown on poor land without benefit of good management practices, proper planting methods, irrigation, fertilizer, or pesticides.

Potential yield

Very little information is available on the yield potential of this crop. We do not know, for instance, whether or not types with larger but fewer leaves are more efficient in light absorption and photosynthesis, or whether fruiting potential and efficiency can be improved.

Yields in excess of 3,000 kg/hectare have been obtained in Iran through the use of selections from available local types grown under experimental plot conditions with irrigation and good crop management practices.

Problems of production

Varieties: Varietal improvement programs have been carried on in India for about 60 years. However, the available genetic base for improvement has been too narrow to make any really significant improvement. Because of the nature of the plant and the very small flowers, hybridization by hand pollination is very difficult. Most programs have consisted of making selections in existing cultivars. As a result, there are no really superior varieties available that incorporate characters such as high-yield potential, resistance to major diseases, and response to good management.

Diseases: The major diseases - chick-pea wilt and chick-pea blight - limit production of this crop almost annually in the main production areas of Asia.

Wilt is caused by a complex of factors all related to reduced capability of the plant to absorb water; these include low rainfall, soil salinity, and nematodes. Although several pathogens have been isolated and reported, no organism consistently pathogenic and giving wilt symptoms has been found. In some years the disease causes severe reductions in yields.

Blight is caused by a fungus, Ascochyta rabiei. It spreads most rapidly when rainfall is abundant during the growing season. It has been a major deterrent to production for many years. Yield reductions may reach close to 100 percent during years of severe attack. Chick-peas have almost completely disappeared from the Azerbajan area in northwestern Iran as a result of repeated crop failures caused by this disease.

Other diseases of bacterial, fungal, or viral origin occur but are of minor importance compared with wilt and blight.

Insects: Chick-peas are relatively free from any serious insect pests. Seldom are insects a limiting factor in production. Bollworm (Heliothis armigera) attacks the seed in developing pods and may cause as high as 10 percent reduction in yield. Timely spray with insecticide can control this insect, however.

Production practices: Like all other food legume crops, chick-peas are grown as a residual crop, with little care from planting to harvest. Little is known as to what production practices the crop will respond to. Chick-peas are considered drought-resistant and are reputed not to respond to irrigation beyond once or twice at critical growth periods, such as at seed germination and beginning of flowering. However, in Iran, with regular irrigation throughout the growing season, this crop has shown marked increases in yield.

As long as the farmer has no assurance of producing a crop because of the severity of disease damage, he is not likely to be interested in applying other input factors. Disease-resistant varieties must come first before a package of cultural practices can be developed and recommended to the cultivators.

Present research

The best program of varietal improvement is at the Haryana Agricultural University in Hissar, India. It is in the center of India's main chick-pea area (1.5 - 2 million hectares). A good varietal improvement program is being conducted by Dr. Satish Chandra, with emphasis on blight and wilt tolerance and response to input practices of fertilization, irrigation, etc. This program is making good use of germplasm provided by the USDA/AID Regional Pulse Improvement Project for broadening its genetic base.

Other Indian institutions such as the Indian Agricultural Research Institute, New Delhi; the Uttar Pradesh Agricultural University, Pantnagar; the Uttar Pradesh Department of Agriculture, Kanpur; the Madhya Pradesh Agricultural University, Jabalpur; and others also have chick-pea programs of varying degrees of intensity and quality.

In West Pakistan, the Agricultural University, Lyallpur, has recently taken steps to upgrade and intensify its research program on chick-peas.

In Iran, the USDA/AID Regional Pulse Improvement Project, in collaboration with national programs, has been carrying on a multidisciplinary research program on chick-peas and other food legumes.

Chick-pea improvement programs of minor importance are being carried on in several countries around the Mediterranean: Israel, Jordan, Lebanon, Turkey, Egypt, Greece, Spain, Morocco, and others.

The following is a partial list of institutions and workers engaged in chick-pea research:

AFRICA

United Arab Republic

Ministry of Agriculture
Research Station
Giza, Cairo

Selection program for varietal improvement of large white-seeded types grown under irrigation

ASIA

India

All-India Coordinated Pulse Project, ICAR
Indian Agricultural Research Institute
New Delhi

(See Pigeon Peas)

(India)

Haryana Agricultural University
Hissar

S. Chandra	Breeder
M. K. Moolani	Agronomist

Extensive breeding program with emphasis on high yield, disease resistance, earliness, and response to fertilizers and other input factors. Several varieties have been released in recent years for specific areas and growing conditions (such as dry-land versus irrigation, high versus low incidence of wilt or blight diseases) and end product utilization. S. Chandra has also begun phytogenetic studies of the various chick-pea species.

Punjab Agricultural University
Ludhiana

K. B. Singh	Breeder (pulses)
J. S. Chohan	Pathologist
H. Singh	Entomologist

Uttar Pradesh Agricultural University
Pantnagar

(See Pigeon Peas)

Uttar Pradesh State Department of Agriculture
Kanpur

(See Pigeon Peas)

Iran

(See Cowpeas)

Israel

Hebrew University of Jerusalem
Rehovot

Research on disease resistance, particularly Ascochyta blight, and varietal improvement

Pakistan

Agricultural Research Station
Dobri

Gordon McLean	IRRI agronomist

Fostering work on chick-peas as a rotation crop with rice in southern region of West Pakistan; germplasm is being screened for suitable types and for wilt resistance

Ayub Agricultural Research Institute
Lyallpur

F. C. Quereshi	Cereal and pulses breeder

West Pakistan Agricultural University
Lyallpur

M. Aslam	Geneticist
M. A. Khan	Breeder
A. O. Shaw	(Washington State University/AID)

Staff members in departments of pathology, entomology, agronomy

With assistance from U.S. AID a coordinated program is being developed. Emphasis in chick-pea on screening germplasm for resistance to Ascochyta blight and chick-pea wilt

Turkey

University of Ankara
Ankara

Dr. Tosun	Botanist

Has over a number of years assembled a good collection and studied various cultivated and wild types of chick-peas

UNITED STATES

California

Department of Agronomy and Range Science
University of California
Davis

C. L. Tucker

Breeding for resistance to Fusarium wilt and curly top; breeding for seed size; breeding systems and genetics

SOYBEANS
(*Glycine max*)

Origin and distribution

There is little doubt that the soybean plant originated in Mainland China, from where it was introduced into Korea and Japan probably some 2,000 years ago. The first records of the introduction of soybeans into the Western Hemisphere date back to about 1700 A.D., while the first published account of the plant in the United States appeared in 1804. The first large-scale introduction of numerous varieties into the United States was done by the U.S. Department of Agriculture beginning in 1898.

World acreage of soybeans is about 33.5 million hectares, of which nearly 50 percent is in North America and an estimated 39 percent in Mainland China. Of the total production of 43 million tons, 69 percent is produced in North America and 24 percent in China. Brazil, the U.S.S.R., and Indonesia are also significant soybean producers. Brazil in particular has made considerable increases in acreage and production in very recent years and is now the world's third largest producer.

Growth habit and utilization

The soybean is an annual herbaceous plant of erect to semi-erect plant habit. It has a considerable range of plant height determined mainly by genetic factors but also by environmental conditions and by photoperiodic response. Plant height under normal conditions of growth seldom exceeds one meter. Plant maturity varies greatly depending on the latitude at which the crop is grown. In Canada, where the season is short, adapted varieties mature in 90 days or less; in the long-season areas of the southern United States, varieties may take 150 days.

Common seed colors are yellow, green, black, and varying shades of brown. They occur three to five per pod and 1,500 to 2,000 seeds weigh about one pound.

Soybeans are primarily grown for oil extraction purposes, the meal after extraction being a by-product. In oriental countries, however, soybeans are used widely for the preparation of such products of fermentation as tempe, tofu, and miso. A small volume is directly consumed as a vegetable.

In the United States most of the soybean oil is used in edible products, and the meal, for animal feed. Oil and meal are also used in manufacturing processes of plastics, paints, emulsifiers, and other products. In recent years, many new edible products have been developed which include considerable quantities of soybeans. Acceptable food products from soyflour have given excellent results when fed to people subject to malnutrition.

Because of its wide adaptability as a crop and its high content of protein and oil, both of which are in short supply in the world, an almost universal interest in soybeans has developed on a worldwide basis.

Nutritive quality

Soybeans are the leading source of the world's supply of vegetable oils. They contain about 18 percent oil and 36 to 40 percent protein. About 80 percent of the fatty acids in the oil are unsaturated. The level of linoleic acid is higher than is considered desirable for human consumption and is suspected of contributing to instability and off-flavors.

Soybean protein is of high quality. The amino-acid distribution very closely approximates that of animal protein. Soybean protein, like that of most food legumes, is deficient in methionine.

Although soybeans appear to be an attractive source of protein, it must be recognized that soybean protein, unlike that of other food legumes commonly grown in developing countries, is not directly utilizable. Boiled or otherwise directly prepared, soybeans, except in the green stage, are unacceptable to most people.

Soybeans contain relatively high quantities of certain antimetabolites, including a trypsin inhibitor and hemagglutinating factors. They are also relatively high in flatus-producing factors.

Yields

National average reported yields range from about 2,500 kg/hectare in Canada to less than 700 kg/hectare in Korea and the U.S.S.R. The U.S. national average is about 1,700 kg/hectare but yields as high as 6,000 kg/hectare have been obtained.

Low yields obtained are due to the use of unadapted varieties, poor crop management practices, damage due to diseases and insect pests, or harvest losses.

Potential yields

Although it is known that present average yields of soybeans can be at least doubled by the most careful use of all known production practices, little information is available on the yield potential of this crop. It is known that only about one third of the flowers produced on a plant actually set fruit and produce seed. Basic research will be needed to discover how this fruiting efficiency can be improved, by giving attention to the plant's structure, its nutrition, its photosynthetic capacity, and other factors.

Problems of production

Varieties: Because of the photoperiodic response of almost all soybean varieties, it is essential that the correct variety be selected for each particular location. The soybean areas of the United States and Canada have been divided into rather narrow zones, for each of which specific varieties have been developed. This is not the case, however, in countries where soybeans are just being introduced. Latitude is not the only criterion for the expression of the photoperiodic characteristic, and varieties may respond differently in the tropics or subtropics. Photoperiodism is not a bar to successful soybean production in the tropics, but it must be taken into account in the selection of potential varieties. Some American varieties have been successfully transferred to certain countries, notably India and Brazil, but considerable varietal development, testing, and production research appear needed in others.

Diseases: There are numerous diseases which may limit soybean production.

Foliar diseases

Bacterial blight	*Pseudomonas glycinea*
Bacterial pustule	*Xanthomonas phaseoli*
Wildfire	*Pseudomonas tabaci*
Frogeye leaf spot	*Cercospora sojina*
Target spot	*Corynespora cassiicola*
Brown spot	*Septoria glycines*
Downy mildew	*Peronospora manshurica*
Bud blight virus	
Soybean mosaic virus	
Yellow mosaic virus	

Root and stem diseases

Phytophthora rot	*Phytophthora megasperma*
Stem canker	*Diaporthe phaseolorum*
Brown stem rot	*Cephalosporium gregatum*
Rhizoctonia root rot	*Rhizoctonia solani*
Pythium root rot	*Pythium ultimum*
Sclerotial blight	*Sclerotium rolfsii*

Seed diseases

Purple stain	*Cercospora kikuchii*
Pod and stem blight	*Diaporthe phaseolorum*
Soybean wilt	*Corynebacterium* sp.

Insects: The soybean serves as host to numerous insect pests. The effects of injury may vary from slight reduction in yield to complete destruction of the crop. Infestations of stinkbugs, velvet bean caterpillars, saltmarsh caterpillars, corn earworms, and other insects may completely defoliate or otherwise ruin a crop.

Leaf feeders

Bean leaf beetle	*Cercotoma trifurcata*
Mexican bean beetle	*Epilachna varivestis*
Spotted cucumber beetle	*Diabrotica undecimpunctata howardi*
Velvet bean caterpillar	*Anticarsia gemmatalis*
Saltmarsh caterpillar	*Estigmene acrea*
Potato leafhopper	*Empoasca fabae*

Pod feeders

Corn earworm	*Heliothis zea*
Stinkbugs	*Pentatomidae*
Stinkbugs	*Acrosternum hilare*

Root feeders

Seed corn maggot	*Hylemya platura*
White grubs	*Phyllophaga* spp.

Nematodes: Several nematodes are known to damage soybeans. The following have been identified:

Root knot	*Meloidogyne incognita acrita*
Southern root knot	*Meloidogyne incognita incognita*
Northern root knot	*Meloidogyne hapla*
Peanut root knot	*Meloidogyne arenaria*
Javanese root knot	*Meloidogyne javanica*
Soybean cyst	*Heterodera glycines*
Sting nematodes	*Belonolaimus gracilis*
Sting nematodes	*Belonolaimus longicaudatus*

Production practices: Several conditions can severely limit soybean production. Among the most serious are: 1) soil conditions that reduce seed germination and emergence; these include hard-crusted surface through which the weak seedling cannot penetrate, and saline soils; 2) insufficient moisture to provide good vegetative growth and flowering; 3) heavy incidence of diseases and insects; 4) heavy shattering and seed losses.

In most, if not all, soybean production areas, soybean yields are reduced considerably unless the seed is inoculated with proper rhizobial bacterial cultures.

Present research

Soybeans have been the object of more research effort than any other food legume crop. Much of this research has been done in the United States and Canada. Research has also been carried on in Brazil, Colombia, Ecuador, Chile, Uganda, Mexico, El Salvador, Honduras, India, Indonesia, Japan, and the Philippines.

The following is a partial listing of institutions, staff, and activities involved in soybean research:

AFRICA

Uganda

Makerere University
Kampala

Colin Leakey	Pathologist-breeder
R. W. Radley	Breeder-agronomist
P. Rubaihayo	Agronomist

Varietal development and testing; development of package of practices for soybean production in Uganda (program just beginning)

ASIA

India

Indian Council of Agricultural Research
Indian Agricultural Research Institute
New Delhi

All-India Coordinated Soybean Scheme

H. B. Singh	Coordinator

(India)

Uttar Pradesh Agricultural University
Pantnagar
and
Jawaharlal Nehru Agricultural University
Krishnagar, Jabalpur

Coordinated Soybean Research Project, in cooperation with U.S. AID-University of Illinois contract team

Program of variety introduction, testing, development; disease and insect control; fertilizer, rhizobial inoculation and other cultural practices; utilization, market development, and economics

Japan

Hyogo Agricultural College
Laboratory of Plant Breeding
Sasayama

T. Nagata

Phenological studies of soybean types

Ministry of Agriculture and Forestry
Regional Soybean Laboratory
Hokkaido Experiment Station
Hokkaido

K. Gotoh — Breeder-agronomist

Research in genetics and breeding; varietal development for yield, high oil content, disease resistance, nematode resistance, cold tolerance

Tohoku National Experiment Station
Tohoku

Hisa Kazu Oizumi — Agronomist-physiologist

Research on plant structure and development

National Institute of Agricultural Science
Soybean Laboratory
Kitamoto, Saitama

Juro Fukui — Physiologist

Studies on day length sensitivity

CANADA

Canada Department of Agriculture
Research stations at Ottawa and Harrow, Ontario

R. I. Burzell	Breeder at Harrow, in charge of varietal development

University of Guelph
Guelph, Ontario

J. W. Tanner	Agronomist
G. E. Jones	Crop Science Department

Varietal development and testing; weed control; agronomic practices

EUROPE

England

Tropical Products Institute
London

W. R. Stanton

Fermentation process in food preparation of soybeans

LATIN AMERICA

Brazil

Department of Research (EPE), through various regional research institutes and experiment stations

F. J. Vernetti	Coordinator

National program is coordinated by National Soybean Commission of the Brazilian Government and U.S. AID and U.S. university contracts

Programs are in varietal development, testing, and crop management practices

Chile

Instituto de Investigaciones Agropecuarias
La Platina

Vital Valdivia	Breeder

Varietal introduction and testing; use of herbicide, fertilizer, rhizobial inoculation, mechanization

Colombia

Instituto Colombiano Agropecuario
Palmira

Luis Camacho — Director, Grain Legume Program, ICA

Varietal development, testing, disease resistance, cultural practices

Ecuador

Instituto Nacional de Investigaciones Agropecuarias

E. Calero — Leader, oil crops program, Boliche and Portoviejo Stations

Varietal introductions, cultural practices, weed control

El Salvador

Centro Nacional de Agronomía
Santa Tecla

Varietal testing (no breeding), crop management work

Honduras

United Fruit Company
La Lima

K. S. Hsu — Agronomist

Varietal development and testing

Mexico

Government of Mexico Experiment Stations at Obregón and Culiacán

C. Barriga — Agronomist at Obregón

Varietal evaluation and selection

UNITED STATES

Arkansas

University of Arkansas
Fayetteville

C. E. Caviness — Agronomist
Staff members of university departments

Breeding; genetics; pathology; entomology; weed control; crop nutrition and environmental effects on production

California

University of California
Los Angeles

K. C. Hamner	Physiologist

Studies on flowering and fruiting in relation to photoperiod

Florida

University of Florida
Gainesville

K. Hinson	Breeder (USDA)

Development of late-maturing varieties for southern regions

Illinois

University of Illinois and U.S. Regional Soybean Laboratory, USDA
Urbana

R. L. Cooper	Agronomist in charge
R. L. Bernard	Breeder

Staff members of university departments and USDA

Coordination of regional variety development and testing for the northern United States; breeding, genetics, pathology, physiology, entomology, nematology, soil and water relations, crop management, chemical and quality research; maintenance of germplasm collection of early-maturing material

Indiana

Purdue University
Lafayette

A. H. Probst	Breeder (USDA)
K. Athow	Pathologist

Staff members of university departments and USDA

Breeding, genetics, disease control, fertility and crop management

Iowa

Iowa State University
Ames

J. M. Dunleavy (USDA)
Staff members of university departments and USDA

Genetics, breeding, disease control, insects, physiology, weed control, crop management practices, growth regulator studies

Maryland

USDA Plant Industry Station
Beltsville

B. E. Caldwell	Leader, USDA soybean investigations
J. T. Holstum	Leader, weed control research
J. M. Good	Leader, nematology research

Special emphasis on photoperiodism, microbiology, rhizobial bacteria and nitrogen fixation, nematology, and herbicide research

Minnesota

University of Minnesota
St. Paul

J. W. Lambert — Breeder
Staff members of university departments and USDA

Genetics, breeding, pathology, physiology, weed control; special research on role of light and carbon dioxide in plant growth

Mississippi

Delta Branch Experiment Station
Mississippi State University and USDA

E. E. Hartwig — Breeder (USDA)
Staff members in various disciplines

Genetics, breeding, pathology, weed control, entomology, engineering; coordination of regional variety development and testing for the southern United States; maintenance of germplasm collection of late-maturing material

Missouri

University of Missouri
Columbia

V. D. Luedders — Agronomist
Staff members of university departments and USDA

Genetics, breeding, pathology, entomology; development of varieties with resistance to soybean cyst nematode

North Carolina

North Carolina State University
Raleigh

J. P. Ross	Pathologist (USDA)
C. A. Brim	Agronomist (USDA)

Staff members of university departments and USDA

Genetics, breeding, pathology; special emphasis on quantitative genetics and biometrical genetics

U.S. Private Industry

Several private companies are conducting soybean research, mostly in varietal development and seed production; among them are:

Coker Seed Company
Hartsville, South Carolina

Soybean Research, Inc.
Mason City, Illinois

Peterson Seed Company
Ames, Iowa

Teweless Seed Company
Milwaukee, Wisconsin

PEANUTS
(*Arachis hypogaea*)

Origin and distribution

The peanut in all likelihood originated in South America, probably in Peru and Brazil; from there it was spread by the Indians to all areas of the American continents where it could be grown and was taken to every other continent by traders. Evidence for possible origin in Africa or Asia has been presented but is inconclusive. A number of wild species have been found abundantly distributed from the Amazon River through Brazil, Bolivia, Paraguay, Uruguay, and northern Argentina.

Peanuts are probably the most important food legume crop in the tropics and subtropics. Total estimated world acreage is 17.6 million hectares, producing some 15 million tons. Of this, Africa with 28 percent and India with 30 percent are the largest producers. Latin America produces 8 percent of the total, mostly in Brazil (6 percent), and the United States produces about 6 percent. Average yield on a worldwide basis is about 850 kg/hectare, but some areas have reported much higher yields.

Growth habit and utilization

Peanuts are an annual crop of herbaceous plant type. They have a great range of variability, but plant height seldom reaches over 12 to 15 inches.

There are two main systems of classification of the cultivated peanut, both of which are based on branching pattern and plant growth and on characters of pods and seeds. Three main types are recognized: Valencia, Virginia, and Spanish. Valencia and Spanish types may be either erect or spreading. They differ in location of reproductive nodes on the plant, in color density of the leaves, and in coarseness of leaves and stems. In Virginia types, there are normally two seeds per pod, and the seeds have a dormancy of 30 days or more. The seeds may be quite large. Spanish seeds are usually small and round; there are two per pod, and they are without dormancy. Valencia types may have as many as five seeds per pod; there is no constriction between seeds in the pods, and seeds exhibit no dormancy.

Generally Spanish and Valencia types are early maturing (85 to 110 days), as compared with Virginias (105 to 160 days).

Peanuts are generally planted on lighter textured, sandy soils. This is not because they will not do well on heavier textured soils. The principal reason is the greater ease of harvest, because sandy soil does not stick to pods or cause as much discoloration.

The crop is mostly planted as a summer crop and grown on natural moisture. The crop in Texas and Oklahoma covers the largest area where peanuts are grown under irrigation.

Peanuts are a very important food and cash crop. A large part of the crop is roasted and eaten directly out of hand, although in some countries extraction of oil is also important.

Nutritive quality

The peanut is an oil seed legume, like soybeans. The seed contains about 25 percent protein and 40 percent oil. The protein of peanuts is not of as good quality as that of other food legumes. It is relatively low in lysine, methionine, and threonine (3.5, 0.96, and 2.7 percent, respectively). There are reports of antimetabolites as well as flatus-producing factors in peanuts. Recent reports of animal poisoning due to aflatoxins in peanuts or peanut meal have led to acceleration of research on this problem. (Aflatoxins are poisons produced by the metabolism of a fungus, *Aspergillus flavus*, which occurs particularly in humid climates when harvest is delayed or when peanuts are not properly cured and stored.)

Yields

Unlike most other food legume crops, the peanut has been the subject of considerable research for many years, mainly because of its value as a cash crop, for both internal markets and for export. As a result, yields, at least in some production areas, have been in the range of 1,000 kg/hectare or better. In the United States, peanut yields of 3,000 kg/hectare are no longer an exception. In other areas, however, in India, Pakistan, and many African countries, yields of around 600-800 kg/hectare are the average.

Low yields in peanuts are due mostly to poor production practices, heavy losses due to insects and diseases, and harvest losses.

Potential yield

The reproductive efficiency of the peanut is quite low. Only a relatively small percentage (10 to 20 percent) of flowers form fruits and reach maturity. Accurate figures are not available, nor would they be the same for all types, seasons, and areas of cultivation. It is known that less than one third of flowers are fertilized and reach the fruiting stage, and many that do are subsequently lost. It appears quite reasonable, therefore, that present yields can be more than doubled if the reproductive efficiency of the crop can be improved and field losses from diseases and insects reduced. If, in addition, farmers, particularly in the developing countries, would adopt better crop management practices, a yield potential of 5,000 kg/hectare appears quite feasible. Such yields have already been recorded from research stations.

Problems of production

Varieties: The use of pure seed of improved varieties by farmers, particularly the small peasant farmers in developing countries such as India or in Africa, is still relatively small. There are as yet no varieties with good resistance to the major insect pests and disease organisms, such as the complex involving *Aphis craccivora* and the rosette or stunt virus disease, Cercospora leaf spot, or *Pythium myriotilum* which causes both peanut wilt and pod rot.

Under certain conditions - but not in all cases - varieties with earlier and more uniform maturity characteristics are needed, so that at harvest a greater proportion of the crop consists of fully mature whole pods and kernels. The long flowering and fruiting periods of most present-day varieties result in harvest losses due to stem breakage in the soil when the fruits are overmature and in the presence of immature fruits.

Diseases: Peanuts are susceptible to a number of diseases. In Africa, Cercospora leaf spot and rosette virus disease spread by aphids are the most serious. Cercospora leaf spot, caused by *Cercospora personata* and the related species *C. arachidicola*, causes chocolate-brown leaf spots, which reduce photosynthetic leaf area and may cause complete defoliation. The extent of damage depends on the stage of development of the plant when infection occurs. It is most severe when plants are attacked during the flowering and early fruiting stages. Leaf spot is most severe in humid areas, where the spread of fungal spores and manifestation of the disease is most rapid. Damage caused by leaf spot has been estimated to range from 15 to 50 percent; in some areas it is even higher. The best long-range method of control lies in the development of resistant varieties. Although varieties with some degree of tolerance exist, no consistent resistance against the fungus has as yet been found. Some measure of control can also be achieved through crop hygiene, for example avoiding continuous peanut culture year after year in the same fields and burying plant residues by plowing and discing. Various fungicides containing copper, sulfur, zinc, or manganese have also given good control, but such methods are not always feasible for use by the peasant farmer because of lack of availability, high cost, and the technical know-how required.

Rosette or stunt virus causes general stunting of the plant, leaf malformation, and an almost 100 percent reduction in yield. Work in Africa has led to the conclusion that at least five viruses are involved, but it is not known whether these viruses, alone or in combination, are the same ones that cause peanut stunt disease in the United States. The virus is spread by aphids, and in the absence of resistant varieties, the main methods of control aim at reducing the aphid vector population and removing the source of the virus in alternate host plants. In Africa important varieties with a high degree of resistance to rosette virus have been produced through breeding.

Stem and root rots occur and may cause serious losses in certain areas in some years. They are usually more serious in the humid than in the drier regions. Several fungi such as Sclerotinium rolfsii, Rhizoctonia, Aspergillus niger, and Rhizopus are causal pathogens of root and stem rot diseases. Seed rots and seedling diseases can be quite important under peasant farming conditions where seed of poor quality is used.

The fungus, Pythium myriotilum, is involved in essentially two diseases. One is peanut wilt; the other, pod rot or pod breakdown. Peanut wilt reduces the vigor and production capacity of the plant, although it does not usually kill it. Pod rot causes a deterioration of pods and seeds and a severe reduction in yield and quality. The relation between the two diseases has not been clarified. Occurrence of wilt is usually followed by pod rot, but pod rot may be quite severe without wilt symptoms having been evident.

A number of other diseases occur, but these are usually of minor importance or are limited to specific areas. The ones mentioned above are the most destructive in the major peanut-growing regions.

Insects: A number of insect pests attack peanuts from the stage of young plant to seed in storage. In spite of the fact that the importance of insect damage is known, relatively little work on insect control has been reported. Many insects occur only locally; and if they are of sufficient importance, control schedules using available insecticides have been worked out. It is not known how much insect control using chemical insecticides is practiced in developing countries, but there is probably little. Reliable data on losses caused by insects are scarce because the crop develops underground and visual estimation is difficult.

A few insects known to cause serious yield losses are:

- Aphids (*Aphis craccivora*), the vector of peanut rosette and stunt virus diseases. The aphids require a very short feeding period on peanuts for transmission of the disease, and their control is difficult. The aphids are capable of living on several alternate host plants including wild species and weeds.
- Leaf hoppers (*Empoasca* spp.), which occur worldwide. Different species occur in different parts of the world. They suck plant juices, causing a severe yellowing of the leaves if not controlled.
- Southern corn rootworm (*Diabrotica duodecimpunctata*), a serious pest of peanuts in the United States, particularly in Virginia and North Carolina. The insect is the larval form of the 12-spotted leaf beetle. The larvae hatch from eggs laid in the soil; they feed on the pods and seeds of the peanut or provide an entry for final destruction by microorganisms.

Production practices: Peanut yields are quite low in many countries, in large part because of poor management practiced by the peasant farmer. Many of the solutions that researchers have found for production problems are geared to the educated farmer who has the know-how and resources to use them. Use of insecticides is generally out of the question for the small peasant farmer; chemicals are too expensive for him, and the required application techniques are too sophisticated. The same is true for fertilizer application, harvesting method, or any other management practice that requires cash outlay or any but the minimum amount of skill.

Present research

Considerable work has been done on peanuts, particularly in the United States, Africa, and India. Research has also been carried on in England, France, the Netherlands, Israel, Brazil, Argentina, Venezuela, and Japan.

The following list indicates some of the locations of present research.

Although the list attests to the extent and quality of research being done, it also shows that a very small portion of the work is carried on in and for developing countries. There has been a great amount of knowledge developed particularly by British workers in Africa but relatively little information has reached the farmer.

AFRICA

Gambia

Department of Agriculture
Cape St. Mary

L. J. Marenah

Varietal improvement; agronomic trials

Kenya

East African Agriculture and Forestry Organization
Nairobi

I. R. Bock — Virologist

Studies on rosette virus complex; five separate viruses involved have been identified

Malawi

Agricultural Research Council of Central Africa
Grain Legume Research Laboratory
Lilongwe

R. W. Gibbons — Breeder and team leader

Varietal improvement; resistance to Cercospora leaf spot and rosette virus

Nigeria

Institute for Agricultural Research
Ahmadu Bello University
Samaru, Zaria

Colin Harkness	Breeder
D. McDonald	Pathologist
A. M. Fowler	Pathologist
H. Caswell	Entomologist

Varietal improvement; cultural practices; agronomic aspects of mycotoxins; breeding for high oil content; breeding for resistance to Cercospora leaf spot and rosette virus

Senegal

Centre de Recherches Agronomiques
IRAT
Bambey

P. Silvestre	Agronomist
J. C. Mauboussin	Breeder
J. F. Poulain	Soils agronomist
M. Delassus	Pathologist

Varietal improvement; cultural practices; fertilization; diseases (Cercospora, other fungi, and rosette virus) and pests; aflatoxin studies

South Africa

College of Agriculture and Research Institute
Potchefstroom

J. P. E. Sellschop	Agronomist

ASIA

India

Indian Council of Agricultural Research
Indian Agricultural Research Institute
New Delhi

All-India Coordinated Research Project on Oilseeds (groundnuts, castor, sesamum)

S. S. Rajan	Coordinator

Varietal trials and other research carried out at various state experiment stations and agricultural universities

(India)

Punjab Agricultural University
Ludhiana

R. S. Sandhu — Agronomist

Varietal improvement; disease resistance

Israel

Hebrew University of Jerusalem
Rehovot

Amram Ashri — Geneticist
A. Z. Joffe — Pathologist

Genetics; varietal development; pod, seed, and soil mycoflora; studies of mycotoxins

Volcani Institute of Agricultural Research
Bet Dagan

Elihu Goldin — Agronomist
Z. R. Frank — Pathologist

Varietal improvement; cultural practices; nature and control of peanut diseases

Japan

Hokkaido University
Sapporo

K. Gotoh

Breeding for early maturity, large seed size

EUROPE

England

Commonwealth Mycological Institute
Ferry Lane
Kew, Surrey

G. A. Gilman — Pathologist

Studies on pod, seed, and soil mycoflora in relation to aflatoxins

(England)

Tropical Products Institute
London

Center for British peanut research work being done in England and abroad; research on mycotoxins

France

Institut de Recherches pour les Huiles et Oléagineux
Paris

P. Gillier

Varietal development and testing, particularly for West African countries

Netherlands

Laboratory of Tropical Agriculture
Wageningen

G. G. Bolhuis — Agronomist

Physiology and production research

LATIN AMERICA

Argentina

Agricultural Experiment Station
Manfredi, Cordoba

J. R. Pietrarelli — Agronomist
M. J. Frezzi — Pathologist

Genetics; varietal improvement; cultural practices; nature and control of diseases

Northeast National University
Corrientes

A. Krapovickas — Geneticist

Taxonomy and evolution of genus Arachis

Brazil

Institute of Agronomy
Campinas, São Paulo

Varietal testing in São Paulo, Bahia, Minas Gerais, and Pernambuco

Venezuela

Center of Agronomic Investigations
Maracay, Arugua

B. Mazzani	Agronomist
G. Malaguti	Pathologist

Varietal improvement; cultural practices; nature and control of diseases

UNITED STATES

Alabama

Auburn University
Auburn

A. C. Mixon	Agronomist (USDA)
G. A. Buchanan	Agronomist
N. D. Davis	Pathologist
U. L. Deiner	Pathologist
N. H. Bass	Entomologist

Cultural practices; varietal evaluation; breeding for resistance to toxin-producing molds; disease and insect control; herbicide studies

Florida

Agricultural Experiment Station
University of Florida
Gainesville

A. J. Norden	Agronomist

Breeding and variety evaluation; several widely used Virginia-type varieties released from this program

Georgia

University of Georgia Experiment Station
Experiment

C. R. Jackson	Pathologist
H. W. Boyd	Pathologist
D. H. Smith	Pathologist
G. Sowell	Pathologist

Studies on nature and control of foliage diseases, soil-borne fungi, and mycotoxins

Georgia Coastal Plains Experiment Station
Tifton

S. A. Parham	Agronomist
D. K. Bell	Pathologist
B. Doupnik	Pathologist
L. W. Morgan	Entomologist
J. F. McGill	Extension agronomist
L. E. Samples	Extension engineer
J. L. Shepherd	Engineer
J. L. Butler	Engineer (USDA)
J. M. Troeger	Engineer (USDA)
R. O. Hammons	Geneticist (USDA)
E. W. Hauser	Agronomist (USDA)

Breeding; genetics; cultural practices; mechanization of harvesting and processing; diseases; mycotoxins; insects; extension education

Maryland

USDA
Plant Industry Station
Beltsville

W. K. Bailey	Horticulturist - Leader of USDA peanut production research
J. M. Good	Nematologist

North Carolina

North Carolina State University
Agricultural Experiment Station
Raleigh

W. C. Gregory	Geneticist
Mrs. M. P. Gregory	Geneticist
D. A. Emery	Geneticist
J. C. Wynne	Agronomist
W. V. Campbell	Entomologist
T. T. Hebert	Pathologist
F. R. Cox	Soil scientist
E. O. Beasley	Extension engineer
J. W. Glover	Extension engineer
J. C. Wells	Extension pathologist
A. Perry	Extension agronomist

Basic studies in genetics, cytogenetics, mutations, breeding; interspecific hybridization between cultivated and wild Arachis species; breeding of Virginia-type varieties; nature and control of virus and other diseases; insects and their control, including inherent resistance; soil fertility studies; extension education programs

Oklahoma

Oklahoma State University
Agricultural Experiment Station
Stillwater

R. S. Matlock	Agronomist
P. W. Santleman	Agronomist
C. C. Russell	Nematologist
D. F. Wadsworth	Pathologist
G. L. Barnes	Pathologist
L. D. Tripp	Extension agronomist
J. S. Kirby	Agronomist
D. J. Banks	Geneticist (USDA)

Genetics; cytogenetics; development of procedures for transfer of desirable genes from wild Arachis species to cultivated peanuts (Dr. Banks); breeding of Spanish-type varieties; cultural practices; fertilizer and irrigation requirements; disease, insect, and nematode control; extension education programs

Texas

Texas A & M University
College Station

R. E. Pettit	Pathologist
J. W. Sorenson	Engineer
N. K. Person	Engineer
Olin Smith	Agronomist
B. R. Spears	Extension agronomist
D. L. Ketring	Physiologist (USDA)

Nature and control of diseases; mycotoxins; genetics and breeding of Spanish-type varieties; mechanization of harvesting and curing; studies of factors involved in growth, flowering and fruiting, seed dormancy and viability; extension education

Texas A & M Plant Disease Laboratory
Yoakum

A. L. Harrison	Pathologist
T. E. Boswell	Pathologist

Nature and control of various diseases and nematodes

Texas A & M Tarleton Experiment Station
Stephenville

C. E. Simpson	Geneticist
S. Newman	Agronomist

Genetics; cytogenetics; breeding and variety evaluation; cultural practices, irrigation, and fertilization

Virginia

Virginia Agricultural Experiment Station
Blacksburg

A. J. Lambert	Engineer
L. I. Miller	Pathologist

Harvesting and curing equipment and procedures; nature and control of diseases and nematodes

(Virginia)

Tidewater Research Station
Holland

M. W. Alexander	Agronomist
R. W. Mozingo	Agronomist
D. L. Hallock	Soil scientist
J. C. Smith	Entomologist
O. E. Rudd	Physiologist (weed control)
A. H. Allison	Extension agronomist
K. H. Garren	Pathologist (USDA)
D. M. Porter	Pathologist (USDA)
P. H. van Schaik	Breeder (USDA)
G. B. Duke	Engineer (USDA)
F. S. Wright	Engineer (USDA)
J. L. Steele	Engineer (USDA)

Breeding and evaluation of Virginia-type varieties; soil fertility studies; nature and control of diseases; pod and seed mycoflora; weed control; mechanization of peanut growing and harvesting; extension education

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